PROGRESS REPORT

JUNEAU ICE FIELD RESEARCH PROJECT, ALASKA

1953

(Office of Naval Research Task Order N9onr-83001)

Prepared by Dr. Lawrence E. Nielsen with Summaries of
Research Work by Members of the Project

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F O R E W O R D

This report endeavors to present the plan of study and observations made during the 1953 summer season of the Juneau Ice Field Research Project. Notes on logistics, equipment and rations, and the medical status of personnel are also included with recommendations for future work. Preliminary results and conclusions are discussed. Final findings in each category of study will be presented at a future date.

The field season was of 88 days duration and essentially from 17 June to 8 September with four days spent in the field in early June. This was divided between Lemon Creek Glacier, the Taku Glacier drainage, and the Taku Valley vicinity of the termini of Taku and Norris Glaciers. The basic eight-man team that performed the work was assisted by a liaison officer in Juneau and had the services of a visiting photographer. During the season two scientific consultants visited the area. These were Dr. John P. Miller of the U. S. Geological Survey and Pennsylvania State College and Dr. William H. Mathews of the University of British Columbia.

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(Map of study area given in Figure 1 at end of text)

I. INTRODUCTION

A. Objectives

The scientific purpose of the 1953 summer season of the project was (1) to gather additional information on the present and past behavior of the Taku Glacier drainage system, (2) to study further the nature of the area, (3) to extend the weather record for another season at the main research station (Camp 10), (4) to complete the triangulation network in the western part of the ice field, and (5) to begin glaciometeorological studies on Lemon Creek Glacier. An additional objective throughout the course of the work was to train the eight-man team and part-time assistants in the art of alpine living, travel, and use of equipment.

B. Personnel

Members of the party, with current affiliations, were as follows:

Dr. Lawrence E. Nielsen, leader, Monsanto Chemical Company, Springfield, Massachusetts.

Richard C. Hubley, meteorologist, Department of Meteorology and Climatology, University of Washington, Seattle.

Richard L. Pierce, plant ecologist, Department of Botany, University of Minnesota, Minneapolis.

A. Philip Muntz, aerial photo interpreter, Department of Geography, University of Wisconsin, Madison.

Austin S. Post, surveyor, Seattle, Washington.

John B. Howe, weather observer and radioman, Aeronautical Icing Research Laboratories, Gorham, New Hampshire.

James H. Hickey, weather observer, mechanic, and radioman, Sacramento, California.

Warren Asa, camp manager, Pana, Illinois.

Anthony Thomas, liaison officer, U. S. Forest Service, Juneau, Alaska.

C. Deployment of Personnel*

Juneau Area

June 4-5: Juneau - Asa, Hickey, Hubley, Nielsen, Post.
" 6-8: Salmon Creek Trail - Hubley, Nielsen, Post.
" 9-16: Juneau - Asa, Hickey, Hubley, Nielsen, Pierce (12th on), Post.

*This schedule is generalized for simplicity.

June 17-30: Camp 10 - Asa, (R. Halmi), Hickey, (J. Miller), Muntz, Nielsen.
(June 25-27: Second Seismic Profile - Asa, (Halmi, Miller), Nielsen.)
June 30-July 20: Camp 10 - Asa, Hickey, Muntz.
July 21-August 15: Camp 10 and upper Taku - Hickey, Howe, Nielsen, Pierce and Post.
(July 24-26: Second Seismic Profile - Howe, Pierce, Post.)
(July 29-August 1: Camp 15 - Howe, Nielsen, Pierce, Post.)
(August 3-5: Mt. Ogilvie Region - Nielsen, Pierce, Post.)

Lemon Glacier Camp

June 18-July 20: Hubley, Pierce, Post (part time); three part time assistants.
July 21-August 17: Asa, Hubley, Muntz.
August 18-31: Asa, Hubley, Howe (till August 24).
September 1-8: Asa, Hubley, Nielsen, Pierce, Post.

Taku Valley

July 8-12: Lower Taku Glacier - Nielsen, Post.
August 18-30: Lower Norris and Taku Glaciers, Taku Point - Muntz, Nielsen, Pierce, Post.

D. Acknowledgments

This field season was again made possible through contract extension of Task Order N9onr-83001, Office of Naval Research. The 1953 summer work represents the sixth field season that has been supported by funds made available by this organization. The Departments of the Army and the Air Force provided equipment and logistical aid. The former department supplied equipment through the Office of the Quartermaster General which obtained items from the Quartermaster Corps, Signal Corps, Corps of Engineers, and Ordnance Corps. The Department of the Air Force, through Air Force Cambridge Research Center, issued orders for military air transport of personnel and provided supplies through Bailment Agreement AF 33(038)-6114. The Air Force 10th Air Rescue Group from Elmendorf AFB, Anchorage, was in charge of air lift of personnel and air supply. The Juneau headquarters of the Tongass National Forest, U.S. Forest Service, made available warehouse space and a liaison officer. The Civil Aeronautics Administration provided radio liaison with Juneau.

Besides the above organizations, the project wishes to acknowledge the assistance of the following: Dr. Donald B. Lawrence and the Department of Botany at the University of Minnesota, Dr. Phil E. Church and the Department of Meteorology and Climatology at the University of Washington, Dr. Kirk E. Stone and the Department of Geography at the University of Wisconsin, Dr. John P. Miller of Pennsylvania State College, Dr. William H. Mathews of the University of British Columbia, Mr. Maynard M. Miller of Cambridge University, England, and Mr. Robert Halmi, photographer, of New York; in Juneau, Mr. Clair Dunlap, pilot; Mr. Hal Weidner and Mr. Harold DeVoe of the Federal Communications Commission; Mr. Claude Brown of the U. S. Weather Bureau; Mr. Rhodes of the Fish and Wildlife Service; Mr. Doug Blanchard, U. S. Customs; Mr. Royal O'Reilly of Taku Lodge; Col. Lars Johnson of the Air National Guard; Mr. Anthony Thomas and Mr. Lacy Johnson of the U. S. Forest Service; and Mr. Ed Mace, Mr. Carl W. Beyer, and Mr. Christie C. Crondahl.

II. GENERAL EXPEDITIONARY MATTERS

A. Logistics

The logistical operations for 1953 were particularly complicated because there were several parties widely scattered over the ice field. The Lemon Creek Glacier Camp was in operation from June 18 to Sept. 8 while Camp 10 was occupied from June 17 to Aug. 15. In addition to these, other operations were carried on over nearly the entire ice field including all branches of Taku Glacier and its terminus region, the lower area and terminus of Norris Glacier, lower Mendenhall Glacier, and Ptarmigan Glacier. Also, short excursions were made to study trimlines and other low level phenomena on Eagle and Herbert Glaciers and the glaciers of Berners Bay "trench." More than the usual amount of traveling was required, as lower Taku and Mendenhall Glaciers had to be visited several times in order to reset and read ablation stakes or to get readings on movement stakes. Also, in order to determine the amount and distribution of snow left over at the end of the summer, all the major branches of the Taku system, except the west branch, were traversed nearly to their upper ends. (This latter branch was also traversed by a party crossing the ice field, but no studies were made on it.)

For Camp 10 and the upper Taku system, the logistical operations were quite similar to those of the past. The 10th Air Rescue Grumman "Albatross" planes were used to transport men and equipment on June 18, July 21, and Aug. 15 between Juneau and the Camp 10 area. An army M29c "weasel" was used for the most part for traveling on upper Taku Glacier when it was in operating condition. One major undertaking though had to be done on skis with the four men involved pulling sleds made from aluminum sheeting.

The first trip to lower Taku Glacier was made in July to set up a series of movement stakes. An Alaska Coastal "Seabee" was used to fly the 3 members of the party and part of their equipment to Taku Lodge. (About 300 lbs. of food and equipment had been shipped previously to Taku Lodge by Royal O'Reilly's river boat.) Douglas Blanchard then moved the party in his outboard motor boat to the extreme east edge of Taku Glacier during high tides. When the work was completed, the party was evacuated in the same manner. A second visit in late August was made by a different route. An Alaska Coastal plane landed a party at Glory Lake on the southwest edge of Norris Glacier. The party then backpacked across the Norris and set up a second camp on the flat ridge between the Norris and the Taku. The movement stakes were then resurveyed from this second camp. Still another party visited the lower Taku (as well as Taku Point area) by the use of O'Reilly's river boat for the purpose of making trimline studies. The lower Norris Glacier and its terminal area were studied using the Glory Lake Camp as a base. An attempt was made to reach the middle Norris Glacier region from this same camp, but the glacier was so rough the attempt was not successful.

The original plans called for a camp on the Norris Glacier near "Guardian Mt." In June some food, gasoline, and a used hexagonal tent were parachuted and dropped free fall for the camp. The schedule was completely upset by the serious illness of one of the members and by O'Reilly's river boat breaking down and thus forcing the postponement of the initial work on the lower Taku. Later in the season, time and competent personnel were never available for the establishment of the camp, so all scientific work in the central Norris Glacier had to be given up. This was very unfortunate as studies are needed on this area to compare with those from the Taku.

The Lemon Creek Glacier Camp was established by an air drop in June. The results were not entirely satisfactory. Over 100 gallons of Blazo (non-leaded gasoline) were lost. Four 5-gallon cans of Blazo in their wooden shipping boxes were attached to a cargo chute by a 1500-pound test rope. This was thought to be sufficient to hold a load of only 150 pounds. However, the speed of the plane was so great that when the parachutes opened, the Blazo was usually ripped away. When it was discovered what had happened to the Blazo, additional heavier ropes were tied to the packages containing several thousand dollars worth of scientific instruments such as electronic recorders. These were then safely landed by parachute. A simple calculation shows that most of the material lost from the chutes could have been saved if the plane had been flying only 10 or 20 M.P.H. slower. Most of the food was in the form of 5-in-1 rations. These were dropped free fall. The plane was flying at too high an altitude so that damage occurred. Many of the cans were badly dented, and a few were broken. Cigarettes in most of the cases "exploded," and only a few good cigarettes could be found in a pack. Estimates on the height of the plane above the glacier varied from 500 feet to 1500 feet.

The second air drop to Lemon Creek Glacier in July was more successful. The gasoline was attached to the parachutes with 5000-pound test rope; this did not break. The plane flew at considerably lower altitude and slower so that the amount of scattering along the glacier was also less.

Toby Dunlap used his little Piper plane to drop mail and a few supplies to Camp 10 and the Lemon Camp. For one month he kept the Lemon Camp supplied with gasoline by dropping it in 5-gallon Jeep cans. He did not attemp to pick up mail from the ice field as was done in past years; this was considered an unnecessarily dangerous operation.

The two "weasels" were not used as much as desired. Some valuable time was lost in digging them out of the snow at the beginning of the season because of several mistakes in caching the weasels at the end of the previous season. The location of the "weasel" cache was easily found as a pipe was sticking out of the snow. Unfortunately, the sketch of the cache did not specify which was the good weasel and which had the broken transmission; neither did the sketch indicate which weasel had the vertical marker pipe attached. (Later we found that the pipe was attached to the broken weasel, so that we then had to do the

job over again and dig out the good weasel.) At Camp 10 we found one or two very poor shovels. We, fortunately, had brought in one or two new shovels so that 3 out of the 6 men available could be kept busy at digging out the weasels. After digging through over 12 feet of snow we found 4 more shovels cached with the weasels.

The weasels were badly crushed by the weight of snow and by the weight of several dozen cases of 5-in-1 and C rations stored in them. A separate report has been written covering the troubles experienced because of this.

B. Equipment and Rations

5-in-1 Rations and C Rations

These furnished most of the food consumed by the 1953 party. In general they were considered very good. The cereal block, however, is no good. No one in the party could eat the cereal blocks although numerous attempts were tried using them in both dry form and cooked. Nearly everyone would have appreciated more fruit in the rations. The sweet chocolate bars were not liked very well; it would have been better if some of the chocolate bars had been replaced by other forms of candy. The coconut candy bars seemed to be rancid with a soapy taste and were not liked by most of the party. The ham and eggs had a very poor texture and appeared to be too finely chopped.

Unfortunately, C rations were only available at Camp 10. Most of the members liked the C rations better than the 5-in-1's. The C rations were especially convenient on the "weasel" trips and offered a variety of choices to suit everyone's taste. The individual portions in the C rations were also better for small parties of two or three than were the 5-in-1's. Most of the cases of C rations were stored the previous winter in the weasels where they were exposed to snow and water. It was found that most of the packages containing the small items such as cigarettes, toilet paper, etc., had been ruined by the water.

Ice Axes

The Army ice axes were far inferior to the European ones. They were too long and too heavy. The metal seemed to be of poor quality, and the wood handles would not stand the wet climate of the ice field. The wet wood would swell and prevent the movement of the metal ring to which was attached the hand sling. The swelling also caused the wood to pull away from the metal parts. In one case the force of the swelling wood broke the rivets in the head and pulled them through the metal.

Tents

The hexagonal tents were found to be quite satisfactory except at the Lemon Creek Glacier Camp where high winds and rain were the normal weather conditions. Under such conditions the tents were filled

with spray so that it was nearly impossible to keep anything dry. Hundreds of pounds of rock around the skirt of the tent were required to hold it down; the constant flapping of the tents soon tore holes around their base. In a specially severe storm the side of one tent was ripped from top to bottom so that it became useless.

The smaller 2-man trail tents were used by trail parties carrying their equipment on their backs. In order to save weight, the 4 tent poles were not used. It seems desirable that this type of tent be slightly redesigned so that a vertical pole at each end replace the present A frame.

C. Radio Equipment and Performance by James H. Hickey

The radio equipment used this year was as follows: for transmitting to Juneau, BC-669, with power unit PE-108 (110V AC). The receiver for the same operation was also the BC-669.

Very little difficulty was encountered with this transmitter this year as it operated with the utmost of satisfaction. The only difficulty was the occasional covering of the frequency 2340kc by Juneau's new radio station, KJNO. The receiver of the BC-669 was also used extensively rather than the AN/GRC-9.

A single wire, horizontal antenna was used with the transmitter. It was anchored to the wooden tower approximately one hundred feet from the research station (Camp 10), and the other end was tied to the top of the station and then down into the radio room.

Originally a BC-223-AX was set up for operation and an expensive doublet antenna was installed. After two days of work trying to get the set to function, the BC-223-AX was replaced and the BC-669 was brought back into the radio shack and put into operation.

D. Cargo Carrier (M29c "weasel") Disposition and Performance by James H. Hickey

The cargo carriers (M29c) did not weather the second winter on the ice field very well. The first carrier to be uncovered this year was the one that was used most during the 1952 season. In 1952 the second carrier which had also been cached in 1951, and subsequently buried by winter accumulation did not appear until the first of September.

When the second carrier was uncovered in 1953 it was approximately two feet below the one in front of it. The body was slanted at an angle of about twenty degrees, while the top was damaged and slanted at an even greater angle. The inside of the carrier was loaded with "5-in-1's" and "C" rations. These were saturated as the hull was full of water. Upon close inspection it was found that the left side (direction of slant) of the body had buckeled under the combined weights of the rations and the snow. The left side was resting on top of the track which made movement difficult.

The following had to be done to get the carrier into running condition:

1. Drain gas tank, as it was full of water.
2. Replace points and condenser in distributor.
3. Remove old spark plugs.
4. Blow water out of cylinders and insert new spark plugs.
5. Replace batteries (12 volt).
6. Clean contacts in distributor cap.
7. Remove, completely disassemble and clean carburetor.
8. Remove electric fuel pump and clean contacts as corrosion had caused the pump to become inoperative.

After the carrier was running there was the problem of getting it out of the snow. The weight of the carrier combined with the fact that the left track was extremely loose because of severely bent springs, hindered driving it up and out. By driving the carriers back and forth and successively building up snow in front and in the rear, the carrier was finally high enough so that it could easily be driven out.

Numerous difficulties were encountered in the course of the season. Since the left track was dragging and pulling to the left when the carrier was used for oversnow travel, the right brake had to be engaged at all times in order that the vehicle travel in a straight line. On one particular trip on the west branch of Taku Glacier, the constant use of the right brake caused an overheating of the rear end and the eventual boiling out of all the grease. Frequent stops had to be made to allow for cooling. It became evident that the carrier would not operate long under these circumstances.. The brake band would burn out leaving the carrier useless.

This condition necessitated driving the other vehicle out of the snow. Despite the fact that it had a bad transmission, it pulled out with comparative ease. The body had stood the winter much better than the other. Of interest to mention also is that the gas tank, although almost empty of fuel, had no water in it. This tank is the rubberized bullet-proof type. The other was the non-rubberized, all-metal kind.

This carrier was used for awhile, although soon the transmission went out. It was necessary in order to have a carrier operating to remove the good transmission from the one with the dragging track and install it in the other. This was successfully accomplished and one carrier was in running order again.

During the summer several mechanical difficulties developed. In both vehicles when the power switch was turned on, the starter became engaged and the engine began turning over. This was before the ignition switch had been turned on or the starter switch had been pressed. Fortunately, however, the starter would disengage once the engine started. The bolts holding the left idler wheel in place became loosened during the summer and almost caused a mishap. Fan belts broke while operating the carriers. The right track of the functioning vehicle is very loose and on turns to the left causes the drive wheel to slip inside the track. This has worn down the teeth on the drive wheel as well as caused a sheering of the track down the middle. Bent springs, brought on by overloading and winter snows, and the buckeled body and frame on the right side are responsible for this condition.

E. Medical Report

For the most part the members enjoyed very good health again this season. However, we were not as fortunate as in most past years. Austin Post contracted bronchial pneumonia about June 20 on the Lemon Glacier. He appeared to be coming down with a cold on the 18th. He hiked into the Lemon Camp the next day and slept in a sleeping bag that had become wet from being left out on the glacier from the air drop on the 18th. Fortunately weather conditions were good enough for a small plane to drop penicillin, the proper food, and other medical supplies, which were administered by other members of the party after Hubley had hiked out to Juneau and consulted a doctor. After about a week, Post was able to hike out to Juneau for a medical check-up and a rest.

Shortly after Post became ill, Pierce caught a cold, but it was soon cured with no ill effects.

On July 10 Post jabbed a piece of a tree limb about the size of a pencil nearly through his hand while climbing through the woods near the terminus of the Taku. By next morning the hand was swollen to about twice normal size so it was soaked in hot water for considerable periods of time and carefully bandaged. The swelling and pain mostly disappeared before a doctor could be consulted on the 13th. The wound continued to run occasionally for several weeks before completely healing. Although the palm of the hand was x-rayed and showed no splinters of wood remaining, it may still contain some wood as hard work irritates the hand yet.

Nielsen was laid up with acute rheumatism or arthritus in the right hip from July 22 to July 25. The attack was apparently brought on either by a rough backpacking trip from the Lemon Glacier Camp on the 20th or from lifting heavy packages during the air lift on July 21. Rest and sodium salicylate cured the attack.

On August 3 John Howe took off his shirt and became very sunburned; he was sick on August 4 but was all right by the next day. Earlier in the season everyone had suffered from sunburn which was mostly on the face.

A few days before arriving in Alaska, Warren Asa had been seriously burned on the right hand and arm by burning paraffin. He had to keep the hand and arm bandaged for about two weeks, but they healed satisfactorily.

III. GLACIOLOGY AND METEOROLOGY

A. Preliminary Report on Glaciology

Taku Glacier

Although the glaciological program for 1953 was quite varied, its main objective was to check the mathematical theory of glacier mechanics by experimental data obtained on the Taku Glacier. Theory predicts certain quantitative interrelationships between the size, shape, and depth of a glacier, the velocity of ice movement, the rate of accumulation of snow in the upper regions, and the amount of melting or ablation taking place in the lower regions of a glacier. If one knows some of these variables which affect the behavior of a glacier, it should be possible to predict the values of the other variables. The Taku should be suitable for such a study since it seems to be a glacier which is in near equilibrium, i.e., neither advancing nor retreating at a rapid rate.

A variable, fundamental to the mechanics of a glacier, is the amount of snow that remains on its surface above the firn line at the end of the ablation season. In order to be able to make a rough estimate of this quantity, a snow survey of the whole upper area of the Taku system was made during the last half of July. Since the survey was made before the end of the ablation season, it is necessary to make certain extrapolations to determine the desired information. This snow survey included the digging of pits near Camp 10A, Camp 10B and 9B (near "Tricouni Mt.") in order to determine the 1952-1953 snow depth at these points. At dozens of other points the snow depth was determined by using a prod rod about 15 feet long. Density measurements were also made at most of these points. Unfortunately, at all the highest elevations (over 5000 or 5500 feet) the true depth could not be determined either because the depth was over 17 feet or no sharp line of destinction existed between the 1952 and 1953 snow covers. Quite probably both of these conditions existed in the very highest areas.

Another very important variable in determining the behavior of a glacier is the amount of ice that melts each year below the firn line. It was not practical to make the measurements on the lower Taku Glacier, so the terminus area of the Mendenhall Glacier was substituted in its place for this year. It is estimated that at least 40 feet of ice melt from the surface of this glacier each year. This tremendous quantity of ice must be replaced by new ice moving down the glacier.

Thus, another important factor in the study of a glacier is its movement. Series of movement stakes were set up along the First Seismic Profile about 2 miles from the terminus of the Taku, along the Second Seismic Profile 10 miles up the glacier, and along the Fourth Seismic Profile 16 miles up the Taku. One of the reasons for putting stakes across the glacier at these locations was to allow calculations to be made of the total quantity of ice moving at various points. From the survey work and the seismic studies made in the past, it is possible to determine the cross sectional area. The quantity of ice flowing through any cross section depends upon the cross sectional area and the velocity of flow of the ice. This calculation is complicated by the fact that the velocity varies across the glacier and also with depth.

By using up to 18 stakes in one area, it was possible to accurately find out how the movement varied across the glacier.

Movement of ice at the edge of a glacier is either zero or small compared to the movement in the center of the glacier. This differential in movement causes the formation of the well-known crevasses running diagonally up glacier from the edges. In the ablation area of the glacier these crevasses usually extend to the very edge of the glacier and do not extend very far in toward the center. The movement stakes indicate that most of the differential changes in velocity of flow occur within the first few hundred yards of the edges. All the central area moves with about the same velocity. Other observations indicate that in the ablation area, there is considerable movement by sliding over the bed of the glacier to its very edge. The relative importance of the two modes of movement, true glacial flow and sliding on the bed, has never been determined. In the accumulation areas it was found that the diagonal crevasses extended farther out into the glacier, but often did not originate at the very edge. The region of differential velocity extended much farther out into the glacier. The region of maximum velocity was not reached till many hundreds of yards in from the edge of the ice. In the lower region of the glacier it was found that any movement stake in or within the crevassed zone near the edge was moving fairly rapidly. In the upper region it was observed that stakes had to be well into the crevassed zone before they showed much movement. It is believed that the phenomena described here are general for most active glaciers, but it is possible that they are just characteristic of the regions studied because of underlying topography, embayments, or turns in the glacier, etc.

It is common practice to put movement stakes in a row across a glacier, but actually it is also possible to learn a lot about a glacier by putting stakes along its length as well as across it. The mathematical theory shows that in the accumulation area the stakes in a longitudinal row should get farther and farther apart with time. This stretching of the distance between stakes is related to the yearly excess snowfall in that location. Likewise in the ablation area the stakes in a longitudinal row get closer and closer together with time. This compression of the distance between stakes can be quite simply related to the amount of ice that melts during a year. Although the calculations are not yet complete, the results so far check the theory at least in a qualitative manner.

Other results predicted by the theory and observed to be true include side-ways motion of ice near the edges and the shape of transverse topographic profiles of glaciers. In the ablation area the ice near the edge not only moves down-glacier but also towards the edge; also the transverse profile tends to be dome shaped, i.e., the ice is higher in the center of the glacier than near the edge. Conversely, in the accumulation region the transverse profile tends to be dish-shaped and the ice not only moves down-glacier but also towards the center. As pointed out by Richard Pierce, these phenomena have important implications in the determination of previous ice levels by studies of scour lines and trim lines.

Tables 1 and 2 give some preliminary results on the movement of ice along Seismic Profiles of the Taku and on the Lemon Creek Glacier.

One of the long term objectives of the project is to eventually predict whether or not the Taku will continue to advance. Most of the signs observed this year seem to indicate the beginning of a recession or at least a temporary decrease in the rate of advance. A small advance was noted on the extreme east side of the terminus region; movement of about a foot in 3 days was observed in July and trees were being pushed over. The terminus area west of the central part of the glacier was very broken and a bulge seemed to be developing in that area. Various recessional characteristics were observed. For instance, on both sides of the glacier for several miles above the terminus the ice was no longer pushing out into the forests but had retreated several yards and the thickness must have decreased many feet. A fresh scour line made by the ice within the past few years is now several dozen feet above the present ice level of Hole-in-the-Wall Glacier. In August a push moraine was observed in front of part of the terminus area; the ice had retreated from this moraine. However, in September the ice had moved forward to the moraine again. From the above conflicting evidence it is easily seen how difficult it is to make predictions about future behavior by studying only the terminal region.

A better way of studying a glacier from the standpoint of making predictions on its future behavior is to see how the ice level changes along its length over the course of several years. A large increase in the thickness of the ice several miles up a glacier will eventually make itself felt as an advance at the terminus. Such an investigation was started this year by setting up a series of paint marks on the rock walls at the edge of the glacier at known elevations above the present ice. These paint markers extend from the terminus to about 17 miles up the glacier. By revisiting these points in future years it will be easy to tell whether or not the ice level is changing. A few markers have also been painted on the rocks along Norris Glacier and at the terminus of the Ptarmigan Glacier.

Comparison of Norris, Lemon Creek, and Mendenhall Glaciers With the Taku

Norris Glacier just west of the Taku has been retreating for a number of years. The actual terminus has not retreated far, but the ice has decreased approximately 300 feet in thickness since 1916. However, the Norris is not a dead glacier, but appears to be amazingly active. Even within one mile of the terminus, the ice along the edge shows all the signs of considerable movement. A simple calculation also shows that considerable new ice must be moving into the ablation region. In the last 37 years the ice has decreased about 300 feet in thickness. However, if the rate of ablation is roughly 40 feet per year, about 1500 feet of ice have melted during this same time. The difference between 1500 feet and 300 feet must have been made up by new ice which has moved into the terminus region.

The Norris Glacier turned out to be a surprisingly interesting glacier. There are two large holes in the ice, one where a stream issues from the end of the glacier and another over a mile from the terminus near the point where the stream from Glory Lake goes under the ice. These two holes are connected by a prominent sag in the glacier; this is probably indicative of a large tunnel or channel under the ice. The lower and larger of the holes exposes over 100 feet of ice in its vertical walls. The bottom ice is old and dirty and is separated from the top white ice by a sharp line of demarcation. This clearly indicates that sometime in the not too distant past the Norris has readvanced and the new ice slid up over the old stagnant ice. Not far from this hole there are several lines of dirt and rock similar to medial moraines. However, they probably are not medial moraines but are more closely related to shear planes which have brought up rock from the bottom of the glacier. All the rock material is sorted and water worn and is not the usual morainic material. The field evidence indicates that Glory Lake was once an ice-dammed lake that dumped itself more or less periodically; fortunately, Mr. William O. Field, Jr. has historical proof that this was true even as recently as about 1926. It is possible that some of the unusual features found in lower Norris Glacier region are associated with this flooding caused by the dumping of Glory Lake.

The Norris Glacier has a large dead branch coming in from the southwest about 4 miles from the terminus. This dead branch has several interesting and unusual features which are worthy of a more thorough investigation. This branch no longer contributes ice to the Norris, but instead some ice from the Norris flows into it. It appears that much of the nourishment of this branch comes from tremendous snow slides from the steep mountain walls along its sides. There are 2 or 3 ice-dammed lakes along this branch. (All of them were dry when we saw them in August.) The largest of these lakes is a beautiful illustration of how an increased rate of ablation or melting causes ice to move in the direction in which this melting occurs. The water in a lake causes an abnormally large rate of melting along its edges and this causes the ice to be forced in towards the lake to compensate for the melting. On the dead branch medial moraines from several directions converge on this one lake. Giant cracks in the ice (not the usual crevasses), unusual medial moraines, and unusual ice formations make the dead branch a fascinating area.

Lemon Creek Glacier is dead compared to the Taku. Tables 1 and 2 show that the Taku moves on one day about as much as the Lemon does in a month. The Lemon now has a very small accumulation area, and in late summer most of it is bare ice. It was found that the region of maximum accumulation is not at the head of the glacier, which is bare in late summer, but a mile or so farther north and also at the mountain sides to the east. The ice of Lemon Creek Glacier must be much thinner than that of most of the Taku. This can be deduced from the surface slope and the velocity of flow.

Mendenhall Glacier is quite an active glacier. Although it is retreating, it must not be far from equilibrium. On the basis of experimental measurements it is estimated that at least 40 vertical feet of ice melt each year from a flat surface. The lower Mendenhall is terribly broken up so that it presents a surface to the sun and air that is many times the area which one would measure from a map. If the crevasses of the Mendenhall could be healed in some way so that the ice had a smooth surface, it might start advancing instead of retreating as at present.

Table I

Movement Data on Taku Glacier

A. On Seismic Profile No. 1. Movement measured perpendicular to Station 1 and the line of stakes. Distance measured from Station 1. Movement measured from July 11 to August 22.

B. On Seismic Profile No. 2. Movement measured perpendicular to upper line of stakes and the upper station on "Goat Ridge". Distances measured from upper station on "Goat Ridge". Movement measured from June 26 to July 25.

C. On Seismic Profile No. 4. Movement measured perpendicular to the line joining Camp 10 (Station 19) and "Shoehorn". Distances measured from Station 19. Movement measured from July 1 to August 2.

Seismic Profile No.	Stake No.	Distance from Station	Total Movement
1	8	2606 feet	110.0 feet
2	3	8166 "	92.7 "
2	4	7265 "	86.3 "
2	6	5117 "	79.7 "
2	7	3800 "	80.1 "
2	8	2522 "	31.3 "
2	9	1471 "	9.9 "
4	1	2281 "	0.7 "
4	2	4909 "	41.4 "
4	3	6831 "	47.8 "
4	4	8817 "	40.5 "
4	5	10911 "	47.0 "

Table II

Movement Data on Lemon Creek Glacier

Movement for stakes 1 to 6 is for the upper glacier. Movement for stakes 7 to 10 is calculated for the lower glacier. In addition to the instrumental error there is a possible error of ± 5 feet due to resetting of the stakes. Movement was measured from July 24 to August 21.

Stake No.	Distance in feet	Total Movement
1	1860	5.1
2	2632	7.4
3	3430	18.8*
4	4343	8.0
5	4886	9.5
6	3646	9.7
7	1908	2.5
8	2677	8.4
9	3744	7.5
10	4844	10.1

*This figure is questionable at this time.

B. Preliminary Report on Meteorological and Glaciological Studies on Lemon Creek Glacier by Richard C. Hubley

Micrometeorological Program

Purpose of the Study The aim of the micrometeorological studies on Lemon Creek Glacier this summer was the collection of data needed to perform a quantitative analysis of the total heat exchange at a snow surface during the ablation period.

Background Heat transfer at an ablating snow surface takes place through absorption of insolation by the snow, heat transferred by molecular conduction between the snow and the adjacent air layer, turbulent transfer of heat (eddy conduction), latent heat released in the process of condensation of moisture on the snow surface or removed from the surface in the process of evaporation, long wave radiation between atmosphere and snow, and heat exchanged by molecular conduction between the snow and precipitation falling upon it. The algebraic sum of these terms is then equal to the total heat flux in the surface snow layer. The field problem is then to measure sufficient micrometeorological parameters to permit calculation of the contribution of each of the individual heat transfer processes to the total heat flux in the snow. If the snow is isothermal at 0°C the total heat flux in the snow is expressible as the amount of ice melted times a constant, and the problem is then reduced to a determination of the contribution of each of the heat transfer processes to the melting of the snow cover.

Field Observations Meteorological observations on the glacier were generally made four times daily at 0800, 1200, 1600, and 2000. Observations were carried out on 47 days of the field season, giving a total of approximately 180 observation periods. Parameters measured and instrumentation used were as follows:

1. Condensation and Evaporation. At the beginning of each observation period, a circular pan, 2" deep by 9" diameter was filled with snow, weighed on a triple-beam balance, and placed on the snow surface. At the end of the period, if there had been no precipitation, the pan was again weighed and the difference between the initial weight and the final weight of the pan and contents divided by the pan area was determined to give the total condensation or evaporation occurring during the period in gm cm^{-2}.

2. Wet and Dry Bulb Temperatures. Because humidity is an important factor in the analysis of long wave radiation, and condensation and evaporation, wet and dry bulb temperatures were measured at one meter above the snow surface with an Assman spring-driven psychrometer.

From these values, together with the standard atmospheric pressure for the elevation of the station above sealevel, the specific humidity as well as the relative humidity can be computed.

3. Precipitation. A standard rain gauge was not available to measure precipitation on Lemon Creek Glacier; however, a circular pan similar to that used for condensation measurements set on the snow surface and weighed at the end of each period during which precipitation fell proved to be fully satisfactory. Contact of the precipitation pan with the snow underneath kept the temperature of the collected precipitation sufficiently low to prevent evaporation.

4. Windspeed. Windspeed, and more particularly, wind shear are extremely important factors in the analysis of heat transfer both by evaporation and condensation, and turbulence. For measurement of windspeed, two anemometers with dials were mounted at nine inches and at seven and one-half feet above the snow surface. At each observation time, the total wind movement in nautical miles during the past period was recorded as shown by the counter dials. The difference in windspeed between the two anemometers is then taken as the shear between 7.5' and 9", while the windspeed at 9" is taken as the shear between 9" and the snow surface, assuming the windspeed at the immediate surface to be zero. It was originally planned to measure windspeed at three or more levels; however, additional anemometers were not available.

5. Synoptic Weather Conditions. To provide a general picture of the weather types under which the various measured micrometeorological situations were found, regular records were kept each period of wind directions, cloud cover in tenths of sky cover, type of clouds visible at time of observation, direction of cloud movement, fog, and types of precipitation occurring, if any.

In addition to the above observations, a 16-point Leeds and Northrup Speedomax operated on a 350 watt generator was used to obtain continuous records of temperature lapse rate, and insolation; and two clock-driven anemometer recorders were used to give continuous records of time elapsed for each mile of wind to pass each anemometer. For the lapse rate measurements, eleven copper-constantan thermocouples were mounted on masts at heights of 0, 1, 2.5, 7.5, 15, 30, 60, 120, 210, 300, and 390 centimeters above the snow surface. The output of each thermocouple was fed into a recording point in the Speedomax, while the remaining Speedomax points were used to record the output of an Eppley 50-junction Pyrheliometer measuring total hemispheric incoming solar radiation. The Speedomax was in operation from 0800 to 2400 or later each day of observation, and while in operation, recorded a complete set of thermocouple and pyrheliometer data every two minutes.

Snow Studies

Purpose of the Studies The purpose of the snow studies on the Lemon Creek Glacier this summer was twofold:

1. In connection with the heat exchange studies described above, to determine quantitatively the amount and time rate of ice-melt in the surface snow layer at the micrometeorological station, and to determine to what degree ablation conditions at the research station were representative of ablation conditions over the glacier above the firn line.

2. To determine the total volume of snow on the Lemon Creek Glacier remaining from the 1952-53 accumulation season at the end of the 1953 ablation season.

Background Mass ablation in the surface layer[1] of a snow cover is equal to the ice melted in the surface layer plus the evaporation of snow from the surface. On Lemon Creek Glacier, evaporation of snow is zero during the ablation season, and total ablation in the snow surface layer is equal to the ice-melt. Because the quantity of ice melted in the snow surface layer cannot be measured directly, it is necessary to express the ice-melt as a function of variables which can be measured. Ablation in terms of centimeters of precipitable water is often expressed as the decrease in thickness of the snow cover times a mean value of snow density. However, depletion in centimeters of water is a measure of mass decrease, whereas the change in thickness of the snow cover is a measure of volume decrease. Therefore, in equating the two by a constant, it is inherently assumed that the snow is incompressible, and the expression represents only a first approximation. Further, because the snow is composed of water in both the solid and liquid form, the quantity of ice melted is not only a function of the depletion in cm of water, but also of the ratio of ice to liquid water in the snow surface layer, and the time-rate change of the ratio. The exact equation expressing the quantity of ice melted as a function of the physical changes in the snow surface layer will be derived and discussed in the later complete report on these studies. The discussion presented here, however, should be sufficient to indicate that to obtain values of ice-melt of sufficient accuracy for use in the micrometeorological heat exchange studies, it is necessary to measure change in thickness of the snow layer with time; snow density, its vertical gradient and variation with time; and the ice to water ratio, also its vertical gradient and variation with time.

Field Observations. Quarter-inch dowels, four feet in length, were driven into the snow to measure lowering of the snow surface. Three at the meteorological station were read and reset four times a

[1] In this study the snow surface layer is defined as the layer between the snow surface and the depth at which penetration of insolation becomes negligibly small.

day, immediately following the meteorological observation. Readings were made to the nearest tenth of a centimeter and the average of tne three readings taken as the representative value of surface lowering for the station site.

Density of the snow surface layer was measured by means of density coring tubes. Density measurements were made at depths of 5, 15, and 25 to 30 centimeters (depth measured to center of tube cylinder). Ice to water ratios were measured by calorimetric methods. Unfortunately without assistance it was not possible to make density and calorimetric measurements as frequently as desirable; however, readings that were made should be sufficient to allow a first approximation to the problem of changes of density and ice to water ratio in the snow surface layer.

To investigate the representativeness of ablation conditions at the micrometeorological station for ablation conditions over the region of the glacier above the firn line, eleven ablation stakes were set, extending from the station to the east side of the glacier at intervals of 500 feet. Originally it was planned to put in a second ablation stake profile across the glacier at a lower elevation, and a third profile extending down the center of the glacier. Again, unfortunately, this proved to be too ambitious a project to be carried out without assistance, and it was not possible to put in and maintain the second two profiles. Readings of the ablation stakes in the one profile were made at two-day intervals during periods of good visibility, and at longer intervals when poor weather made it inadvisable to travel across the glacier alone.

Shortly after arriving on the glacier in June, experiments were made in using a Mt. Rose type snow sampler to measure depth and water content of the 1952-53 snow cover. It was found that after penetrating the snow approximately four meters, the sampler intercepted snow of very high density through which it was impossible to drive the sampler more than a few centimeters. With the help of Mr. Pierce, a snow pit was dug and from direct observation and measurement it was confirmed that the dense, hard-packed snow intercepted by the sampler was the base of the '52-53 snow cover. Throughout the remainder of the season, depth and water content measurements at the site of the micrometeorological station were carried out with the Mt. Rose snow sampler. Near the end of August, with the help of Mr. Howe, three cross-glacier profiles of the depth and water content of the remaining 1952-53 snow cover were run with the snow sampler. Five sample stations were used on each profile, with the stations separated by intervals as nearly equal as possible. An ablation stake was set at each station following the sampling in order that the loss of snow could be measured between the date the sample was taken and the end of the ablation season. During the first week of September, photographs of the firnline and névé region were taken both from the air and ground. The photographs showing areal distribution of snow together with the depth and water content measurements will be used to estimate the total volume of accumulation on Lemon Creek Glacier for the 1952-53 season.

Plans For Laboratory Use Of Field Data

Micrometeorological and Snow Research Studies   Heat balance computations will be made using the direct measurements of the heat exchange components and snow surface layer data collected this summer. The functional relationship of the individual processes of heat exchange to micrometeorological parameters and physical characteristics of the snow will be investigated. The next step will be the analysis of upper air charts covering the North Pacific, Alaska, Bering Sea, and Northwest Canada for the period covering this summer's field season, and from this an analysis of the functional relationship between micrometeorological parameters on upper Lemon Creek Glacier, and the large scale synoptic weather conditions, thereby permitting a discussion of ablation of snow on Lemon Creek Glacier as controlled by the large scale weather patterns.

The above investigations supplemented by the field studies being planned for next summer will constitute in part the basis for the writer's doctoral dissertation.

Investigation of the 1952-53 Glacier Budget   Because it was not possible this season to perform ablation measurements below the firn line on Lemon Creek Glacier, it is not possible to deal with the complete glacier budget for this year past. However, as far as possible the budget of the accumulation region will be investigated. The aim will be to determine qualitatively through use of movement stake data and computations of the volume of net accumulation of snow whether the budget of the accumulation area this year represents a net gain or loss of material, or an equilibrium condition.

C. Weather Observations at Camp 10, upper Taku Glacier

Observations at the main research station at Camp 10 were carried out from 20 June until 14 August. The following data were recorded:

Three-hourly observations, 0700-2200
- Temperature and dew point
- Visibility and sky conditions
- Wind
- Pressure

Six-hourly observations, 0700-1900
- Maximum and minimum temperatures
- Precipitation

Total wind movement, 0700-2200

Instrumentation was as follows:

Signal Corps meteorological shelter on ledge approximately 80 feet from research station
Maximum and minimum thermometers
Thermograph
Anemometer, ML-80, and wind vane on 10-foot mast, located on rock above and approximately 100 feet from building
Anemometer, remote-indicating, and wind vane, located near other anemometer, for wind velocity at observations
Standard precipitation gauge, located on high ledge near anemometers.
Aneroid barometer, ML-102D, and microbarograph on wall of main room of research station

Observations made for the period show a maximum temperature of 69°F. on 26 July and a minimum of 35.2°F. on 30 June; average temperature for the June period was 48.5°F., for July 48.2°F., and for the August period 45.3°F; highest average wind speed was 16 m.p.h. on 14 August; and 2.76 inches of precipitation on 14 August was highest for a daily period. There was no snowfall recorded during the time of observation.

IV. GEOBOTANICAL WORK

R. L. Pierce

Introduction

The primary purpose of the 1953 Geobotanical Program was to determine the height of glaciers emanating from the Juneau Ice Field during the late postglacial Maximum. It was intended that the studies of the 1953 season would be a continuation of similar studies carried out during the 1952 season on the Taku Glacier and that they would be divided into two parts:

(1) Evaluation of the highest determinable past levels of glaciers above timberline, designated "high level" trimlines.

(2) Evaluation of highest past levels of glaciers below timberline, designated "low level" trimlines.

The first part of the season, from the 20th of June to the 12th of July, was devoted to an investigation of the high level trimlines of the Lemon Creek and Ptarmigan Glaciers located in the southwestern portion of the ice field some five miles east of Juneau; on the 25th of July, the trimline of the Taku Glacier on "Goat Ridge", which had been determined by a field party during the 1952 season, was re-examined; on the 30th of July, a reconnaissance party made observations on trimlines of two glaciers of the "Berners Bay Trench" area (Camp 15); the period from the 19th of August, to the 30th of August, was devoted to a study of low level trimlines of the Norris and Taku Glaciers; and the 4th and 5th of September, were devoted to an unsuccessful reconnaissance of the terminus of the Lemon Creek Glacier.

High Level Trimlines of the Lemon Creek Glacier

Personnel: Richard L. Pierce

Equipment: Thommen altimeter, Gurley compass, plant presses, aerial photos.

Permanent stations marked by stakes painted yellow were established along the trimlines of Lemon Creek Glacier on the east slope of that portion of "Cairn Ridge" extending north of Cairn Peak. Elevations of the stations were determined, and observations were made on the character of the geology and development of the vegetation and soil above and below the trimline. Station locations were recorded on "Trace-O-Film" overlays, and plant collections were made from above and below the trimline. The plants have not been identified yet.

Station 53-1

Location: East slope of Cairn Peak.

Elevation: 4200 feet.

Soil Development
Above trimline: Deep brown, ferruginous, micaceous sand, Depth approximately 60 cm.

Below trimline: Negligible, surface covered with loose shaly rock.

Geology
Exposed rock: Granodiorite gneiss and quartz-mica schist.

Dip: Not determinable.

Vegetative Development
Above trimline: Abundant fruticose lichens, *Silene acaulis*, *Antennaria* spp., *Lycopodium* spp., grasses and sedges.

Below trimline: Barren except for portions of vegetation detached from above the trimline during slumping.

Station 53-2

Location: One hundred yards N 18° W of station 53-1.

Elevation: 4180 feet.

Soil Development
Above trimline: Dark brown to black sandy loam. Depth 60cm.

Below trimline: Negligible.

Geology
Exposed rock: Micaceous granodiorite gneiss.

Dip: 45° E.

Vegetative Development
Above trimline: Dense grass cover (*Agrostis* sp.) forming a thick sod.

Below trimline: Barren except for portions of vegetation detached from above trimline.

Station 53-3

Location: Four hundred yards north of station 53-2.

Elevation: 4180 feet.

Soil Development

Above trimline: Deep brown sandy loam. Depth 45 cm.

Below trimline: Negligible.

Geology

Exposed rock: Granodiorite gneiss and quartz-mica schist.

Dip: From west side of ridge on exposed granodiorite gneiss the dip is 80° S 42° E. Two hundred feet north on well exposed ferruginous granodiorite gneiss the dip is 45° N 12° W. One hundred yards south of station 53-3 the dip is 20° E on a hornblende gneiss. These measurements would seem to indicate that station 53-3 is located on an east-west trending anticline plunging east.

Vegetative Development

Above trimline: Similar to station 53-1. Extensive development of fruticose lichens.

Below trimline: Barren except for slump transported vegetation.

Station 53-4

Location: Eight hundred yards north of station 53-3.

Elevation: 4110 feet.

Soil Development

Above trimline: Deep brown, porous sand 35 cm. deep.

Below trimline: Negligible.

Geology

Exposed rock: Ferruginous quartz gneiss.

Dip: 30° N 45° E.

Vegetative Development

Above trimline: Well developed alpine turf with extensive development of fruticose lichens, similar to station 53-1.

Below trimline: Negligible, occassional patches of _Silene acaulis_ and scattered tufts of _Carex_ spp.

Station 53-5

Location: Eight hundred yards northeast of station 53-4 on east slope of Vesper Peak.

Elevation: 4130 feet.

Soil Development

Above trimline: None.

Below trimline: None.

Geology

Exposed rock: Massive granodiorite.

Dip: 30° N 72° E.

Vegetative Development

Above trimline: No turf formation below 4350 feet. Scattered bunch habit grasses and sedges present.

Below trimline: Not conspicuously different from area immediately above trimline. The rock below the trimline is noticeably worked with little accumulation of debris from frost action. Above the trimline the large crystals of plagioclase feldspar in the granodiorite are noticeably weathered and fractured along the cleavage and twinning planes.

Station 53-6

Location: One thousand yards north of Station 53-5.

Elevation: 3750 feet.

Soil Development:

Above trimline: Negligible.

Below trimline: Negligible.

Geology

Exposed rock: Granodiorite gneiss.

Dip: 30° N 72° E.

Vegetative Development

Above trimline: Occassional patches of Cassiope mertensiana, patches of mosses, crustose lichens and tufts of sedges and grass. Sparse cover.

Below trimline: Patches of moss, crustose lichens and tufts of sedges and grass. Negligible cover.

Station 53-7

Location: 1000 yards north of Station 53-6.

Elevation: 3350 feet.

Soil Development

Above trimline: Seldom more than 5 cm. of black organic soil accumulated between strata in protected situations.

Below trimline: None.

Geology

Exposed rock: Granodiorite gneiss.

Dip: 30° N 72° E.

Vegetative Development

Above trimline: Well developed patches of moss-lichen-heath mats in the level areas between strata.

Below trimline: Occasional tufts of grass and sedges as well as small patches of moss.

Station 53-8

Location: Eight hundred yards north of station 53-7 on north side of persistent snow patch.

Elevation: 3050 feet.

Soil Development

Above trimline: Similar to station 53-7.

Below trimline: None.

Geology

Exposed rock: Granodiorite gneiss.

Dip: 30° N 72° E.

Vegetative Development

Above trimline: Similar to station 53-7.

Below trimline: Similar to station 53-7.

Other Observations

It seems quite probable that stations 53-1 and 53-2 are not part of the Lemon trimline series, but belong, instead, to the trimline of a small southeasterly-flowing glacier which has built up two moraines on the extreme southern end of the Lemon Creek Glacier in the area that has been mapped as the "head" of the Lemon. The two moraines of this small glacier indicate two distinctive periods of advance and recession. Though separated by a distance of less than 50 feet at the maximum point of separation and overlapped at other points, the moraine farthest removed from the present position of this glacier has a well developed cover of vegetation consisting of fruticose lichens, Lycopodium spp., Silene acaulis, Cassiope mertensiana, Phyllodoce glanduliflora, Taraxacum sp., as well as other forbs and grasses. Soil development on this moraine varies from extremes of 0 to 80 cm. The inner moraine has a paucity of vegetation supporting only a very few scattered specimens of moss, lichens, legumes and grasses and no soil.

In view of work done later in the season on the terminus of the Norris Glacier the most probable explanation seems to be that the inner moraine represents a period of advance for this small glacier during the very recent past, a matter of some forty years, while the outer moraine represents a period of advance at an earlier date. Unfortunatley this earlier advance seems to have become completely obscured throughout the Lemon Creek Glacier area, except at this point, by the more recent advance.

The question then arises as to just what period of time the older moraine is representative of. The most logical assumption would be to assign it to a period of known glacial activity, the late postglacial maximum, but the advanced conditions of soil and vegetative development found on this moraine make this a tenuous assumption at best. It seems more probable that the older moraine represents a period of advance for the glaciers of the Lemon Creek area that antedates the late postglacial maximum. This theme will be developed more fully in the section on the Norris Glacier.

The eastward plunging anticline which was noted for station 53-3 probably forms a ridge beneath the ice of the Lemon thus separating the Lemon from the small glacier which developed the moraines previously described. That this feature may exist is supported by the fact that a ridge from Observation Peak extends a short distance into the glacier at approximately the position taken by the direction of trend of the anticline from station 53-3.

Several gaps occur in "Cairn Ridge" between the Lemon and Ptarmigan Glaciers which give evidence of past connections between these two glaciers. At the south base of Vesper Peak between stations 53-4 and 53-5 there is a gap oriented east and west with a 5° slope to the east. Here occur large erratics of a garnetized granodiorite gneiss derived from a nearby source. By tracing these erratics to their source in the immediate vicinity it was found that the ice movement was westward from the Lemon Creek to the Ptarmigan at the time of connection.

Several other gaps of a similar description occur in the immediate area; however, immediately north of station 53-3 at elevations above discernible trim gaps occur with erratics and well developed cover of vegetation that indicate a much earlier connection between these two glaciers. It was not possible to determine whether these gaps represented connections during the latter portion of Pleistocene glaciation or were from a later period.

No stations were established at the extreme end of "Cairn Ridge" as there seemed to be no sure line of demarcation for one ice level; however, the small nunatak at the ice fall appears to have been completely covered by the most recent ice maximum. This latter conclusion is based on the lack of vegetation and a large erratic on the summit of the nunatak at an elevation of 2850 feet.

Conclusions on the Lemon Trimlines

Some explanation should be made regarding the lack of information on the relative differences in height between a past high ice level and the present height of the glacier. The main purpose in establishing the stations with yellow markers was to enable reoccupation of the stations at a time when accurate altimeters and assistance would be available. A second choice would have been to sight them in with a theodolite. The situation existing at the end of the season when the Lemon was revisited precluded either alternative, but with the aid of aerial photo overlays no difficulty should be encountered in relocating and occupying the stations next season. It can be stated within the magnitude of accuracy that an average difference of approximately 200 feet exists between the present level of the Lemon and level attained by it during its most recent maximum. This estimate will vary with position.

Assuming that the most recent moraine from the small glacier at the head of the Lemon represents a condition of advance that occurred after the late postglacial maximum, then it is probable that the trimline of the Lemon which was studied during the 1953 season is representative of this more recent maximum than the late postglacial maximum. If this is true then the late postglacial maximum:

1. Did not affect the regimen of Lemon Creek Glacier.

2. Was obscured by a more recent advance.

3. Is present at higher elevations along the ridges but was overlooked because of the more apparent trimline present.

Vegetation and soil development along the trimline studied were apparently more dependent upon parent material than proximity to the trimline. On the easily weathered schistose rocks a well developed alpine turf, of which fruticose lichens were the most conspicuous components, occurred down to the trimline. Below the trimline even on the easily weathered schists vegetation was negligible and patchy at best.

On the granodiorite exposures heath plants, particularly Cassiope mertensiana and Phyllodoce glanduliflora, were the most conspicuous elements of the flora, and well developed heath mats occurred only on the summits. Both immediately above and below the trimline on the granodiorite exposures vegetation development has been negligible, though patches of Cassiope mertensiana did occur down to the trimline and not below it.

High Level Trimlines of the Ptarmigan Glacier

Personnel: Richard L. Pierce

Equipment: Thommen altimeter, Gurley compass, plant presses, aerial photos.

As on the Lemon Glacier, permanent stations were established by placing yellow painted stakes at station locations. All trimline determinations were made on the ridge which borders Ptarmigan Glacier on the west. The situation existing regarding the collection of data and material on the Ptarmigan is the same as stated for the Lemon.

Station 53-A

Location: Extreme south end of Ptarmigan Glacier.

Elevation: 3920 feet.

Soil Development

Above trimline: Upper 10 cm. consisted of a hematite red sand which graded into a light brown to light gray sand. Depth approximately 80 cm.

Below trimline: Indefinite mixture of soil and till. Soil wash and slumping from trimline evident.

Geology

Exposed rock: Thinly foliated hornblende schist and quartz-mica schists.

Dip: 30° N 60° E.

Vegetation Development

Above trimline: Well developed fruticose lichen-moss turf with grasses and forbs.

Below trimline: Vegetation patchy. Silene acaulis most conspicuous element with occassional bunch habit grasses.

Station 53-B

Location: Five hundred yards north of station 53-A on west ridge.

Elevation: 3800 feet.

Soil Development

Above trimline: Developed from weathering of a hornblende schist resulting in a fine textured, black, micaceous, sandy soil. Depth approximately 50 cm. with many rocks in the profile.

Below trimline: Soils evidently washed into crevices of moraine material. Indefinite depth with many rocks in profile from the surface down.

Geology

Exposed rock: Mainly hornblende schists.

Dip: No bed rock exposure in immediate area. At an elevation of 3850 feet 100 yards south of the station the dip was 50° N 60° E on a hornblende schist outcrop.

Vegetation Development

Above trimline: A well developed alpine turf in which fruticose lichens were the main component.

Below trimline: No essential difference in the composition of the vegetation, but the amount was less. Vegetation patchy with less lichen component and more Epilobium latifolium.

Station 53-C

Location: Five hundred yards north of station 53-B. This is not actually a trimline, but is situated on a lateral moraine at the head of an old ice gap through which ice from the Ptarmigan spilled into "Canyon Valley."

Elevation: 3600 feet.

Soil Development

Above trimline: (no information)

Below trimline: Negligible.

Geology

Exposed rock: morainal material consisting mostly of ferruginous quartzite, hornblendite, granodiorite, both massive and gneissic, and pegmatites. Bed rock exposures are: quartz-mica schist, hornblende schists and ferruginous quartzite.

Dip: 30° N 60° E.

Vegetation Development
Above trimline: (no information)

Below trimline: Patchy. Mosses, all forms of lichens, Epilobium latifolium conspicuous along with Silene acaulis, saxifrages and some bunch habit grasses.

Station 53-D

Location: Two hundred yards north of station 53-C on the elevated portion of an old lateral moraine.

Elevation: 3680 feet.

Soil Development
Above trimline: Negligible.

Below trimline: Negligible.

Geology
Exposed rock: Morainal material consisting mainly of ferruginous quartzite and granodiorite gneiss. Bed rock exposures of ferruginous quartzite, quartz-mica schists, granodiorite gneiss and hornblende schists.

Dip: 30° N 72° E.

Vegetation Development
Above trimline: Vegetation patchy consisting of Cassiope mertensiana and Phyllodoce glanduliflora, with various mosses, all lichen forms and bunch habit sedges and grasses.

Below trimline: Similar to the vegetation occurring above the trimline except no Ericads are present.

Station 53-E

Location: Five hundred yards north of station 53-D

Elevation: 3480 feet.

Soil Development
Above trimline: Negligible.

Below trimline: Negligible.

Correction: Later inspection of the position of this station from a vantage point on the glacier revealed that the established station was located 30 to 50 feet below a clearly definable trimline. This error has not been corrected in the field.

Station 53-F

Location: Three hundred yards north of station 53-E.

Elevation: 3000 feet.

Soil Development

Above trimline: Negligible, an unstable slope.

Below trimline: Negligible.

Geology:

Exposed rock: Above the station there is a ferruginous quartzite with contorted expansion folds. No practical means of determining dip.

Vegetation Development

Above trimline: Negligible, patches of Epilobium latifolium conspicuous.

Below trimline: Negligible, patches of Epilobium latifolium.

Correction: Later inspection of this station from the glacier revealed that it was 50 feet below another line of trim though it had been established on an old lateral moraine.

Station 53-G

Location: Three hundred yards north of station 53-F. Established on an old lateral moraine.

Elevation: 2650 feet.

Soil Development

Above trimline: Soil at all depths contained some rock fragments. Dark brown sandy loam from 15-30 cm. deep with 1-2 cm. of a dark organic cap soil. Soil developed on an unstable slope.

Below trimline: Organic cap soil 1/2 to 1 cm. deep developed on a lateral moraine overlies a light gray sand containing numerous rock fragments and pebbles.

Geology

Exposed rock: Quartz-mica schist. No exposures good enough for determining degree and direction of dip.

Moraines: A series of moraines are evident below the trimline. The height of these moraines, from oldest to youngest, is:
(1) 2650 feet, (2) 2642 feet, (3) 2630 feet,
(4) 2625 feet, (5) 2623 feet, (6) 2600 feet,
(7) 2598 feet, (8) 2588 feet, (9) 2583 feet,
(10) 2573 feet.

Other moraines are present which extend down to an altitude of 2400 feet onto the outwash plain in front of the present terminus indicating that the recession of the Ptarmigan from its most easily definable high level position was a complex series of pauses and slight readvances.

Vegetation Development

Above trimline: Well developed heath mats of Cassiope mertensiana, Cassiope tetragona, Phyllodoce glanduliflora and occassional lupines, sedges, and patches of moss.

Below trimline: Epilobium latifolium and Lupinus nootkatensis are the most conspicuous plants, but occassional patches of heath occur and there is a well developed cover of grasses and sedges. A few willows and alders are also present. Progressing downwards from older to younger moraines the vegetation becomes sparser with the occassional heath plants soon eliminated.

Conclusions On the Ptarmigan Glacier Trimline

The conclusions reached after investigation of the trimline of the Ptarmigan are much the same as those reached for the Lemon Creek. The condition of soil and vegetation development point to a much more recent maximum for this glacier than the 200 year old maximum.

High Level Trimline of the Taku Glacier On "Goat Ridge"

Observations of the trimline along "Goat Ridge" were made while accompanying a party surveying the lower Taku movement profiles. Above the trimline occurred well developed heath mats, patches of fruticose lichens, and occasional patches of krummholz composed of Picea sitchensis and Tsuga mertensiana with individual stems up to 4" in diameter immediately above the base. Soil depth was approximately 20 cm. with 1-10 cm. of reddish-brown organic cap soil which graded into a black, sandy soil derived from Pleistocene erratics and bedrock. The vegeta-

tion down the west slope of "Goat Ridge" becomes patchy even above the trimline; probably the result of persistent snow patches. Below the area of trim fingers of vegetation extend down the moister portions of the slope from the continuous cover above. The exact line of trim is difficult to discern from any position on the slope though the slope is littered with erratics and striations which trend southwest. There does seem to be a perceptible change in amount of vegetation, but little difference in kind of vegetation below the trimline as compared with above the trimline. Mosses are conspicuous with patches of heath, foliose lichens, bunch habit sedges and grasses and saxifrages. Soil development is negligible. The trimline elevations are apparently of the magnitude recorded by previous parties for this location.

Trimlines of the Berners Bay Glaciers

The trimline which seems evident on aerial photograph No. SEA 126-213 for the small glacier below the "Tusk Peaks" is not at all apparent from the valley. What appears to be a well-defined trimline of the late ice maximum on the photographs for this valley is, in reality, a broad outwash fan with recessional moraines of very recent origin. Epilobium latifolium is the most abundant and frequent plant found on this recently exposed material though Calamagrostis canadensis, sedges, willows, and alders are also abundantly present. A zone of alders with individual stems 6-10 feet high and 1-3 inches in diameter extends as a continuous cover from the line which appears as a trimline on the photograph to the summit of the east slope of the ridge between "Madman" and "Big Tree" Glaciers. A line of demarcation between this thick zone of alders and alders growing on well developed turf appeared to exist at a height of 300 to 400 feet above the valley floor. Due to circumstances beyond the party's control the slope was not climbed.

The stream which flows from the front of "Madman" Glacier through "Fireweed" Valley and under "Big Tree" Glacier formed an ice-dammed lake in "Fireweed" Valley in the very recent past. From the condition of the vegetation which is predominatly Epilobium latifolium it would appear that the lake existed up to 10 years ago. The depth of the lake, indicated from old shore lines, was 100 feet.

"Big Tree" Glacier (Glacier with ogives seen from Camp 15)

Conspicuous trimlines are present along the lower two-thirds of the "Big Tree" Glacier, and, as seen from Mt. Ogilvie, very well demarcated trimlines are characteristic of the "Antler System" as a whole. As these glaciers extend throughout most of their length below timberline, the trimline is easily distinguished by the trees which extend down to the trimline. The best evidence for the existence of a higher ice level on the "Big Tree" Glacier is the presence of a well developed lateral moraine approximately 8 feet high and 8 feet wide perched 385 feet above the present edge of the ice. This moraine starts at an elevation of 2410 feet approximately 1/2 mile south of the juncture of "Big Tree" Glacier with "Fireweed" Valley and extends for

a distance of 500 yards north to the bare north slopes of "Fireweed" Valley where its elevation is 2260 feet. Several other moraines can be seen 2 to 10 feet below this largest moraine. These extend for a short distance, but are lost on approaching the bare north slopes of "Fireweed" Valley. The abrupt termination of these moraines would seem to indicate the possibility of a glacier having extended down the full length of "Fireweed" Valley and having joined "Big Tree" Glacier causing the lateral moraines to become medials, thus eliminating the possibility of extending the moraines north of the mouth of "Fireweed" Valley.

Heath mats of Cassiope mertensiana and Phyllodoce glanduliflora, grasses, sedges, saxifrages, etc. are as well developed below the trimline as above. The most conspicuous difference in vegetation is exhibited by the woody plants. Below the trimline alder is the predominant woody plant with occasional specimens of Tsuga mertensiana up to 3 inches in diameter a few inches above the base. Above the trimline formed by the moraine, Tsuga mertensiana predominates with at least one specimen up to 20 inches d.b.h. (diameter breast high) occurring only 20 feet away from the moraine.

Low Level Trimlines of the Norris Glacier

Personnel: R. L. Pierce, A. P. Muntz

Equipment: Increment borers, aneriod altimeters, saw, aerial photos.

The material collected on the Norris trip has not been carefully analyzed, but cores and sections which were roughly analyzed at the time of collection reveal that any evidence of a 200 year old maximum having occurred on the Norris has been obliterated by a more recent maximum which occurred approximately 40 years ago. This situation is evidenced by lateral moraines juxtaposed to post first generation forest on east and west "Glory Ridges" and on the southwest slope of Norris Ridge. Trees that were tilted during the formation of the moraine on "Glory Ridge" were cored and sectioned and should, when analyzed, give the exact date of the maximum advance of the Norris during the recent past. Some cored trees immediately adjacent to the moraine were roughly estimated at 300 years of age indicating that the maximum of the Norris during the early 1900's reached a higher level than any advance within the past 300 years.

Altimeter readings, which have not been assembled into final form, place the height of the ice edge of this recent maximum 360 feet above the present edge of the ice in the vicinity of "Glory Lake" and 390 feet above the present ice edge on the southwest slope of Norris Ridge in the vicinity of "Bed Rock Camp".

Possible Correlation of Lemon Creek and Norris Advances

From the evidence of this recent maximum on the Norris the assumption can be made that the maximum determinable on the Lemon Creek and Ptarmigan Glaciers is also of recent occurrence. This would explain why the areas below the trimlines on these two glaciers are practically devoid of vegetation. It would also explain why the inner moraine of the small glacier at the head of the Lemon Creek and the lateral and terminal moraines of the Ptarmigan are negligibly weathered. If it is also assumed that ice level increases comparable in magnitude to this recent increase took place 300 to 500 years ago in the Lemon Creek Glacier area, then the outer moraine formed by the small glacier above the Lemon may belong to this earlier advance. The advanced condition of soil and vegetation development is more easily explained this way than if it were assigned to the 200 year old maximum.

Such assumptions would have to take into consideration the reasons for a comparable regimen for the Ptarmigan, Lemon Creek and Norris Glaciers, and reasons why variations exist in the regimen of glaciers emanating from the same ice field. The Lemon Creek and Ptarmigan are, for all practical purposes, nourished from the same general area and could, with a slight increase in accumulation, become connected in their accumulation area. The "Dead Arm" tributary of the Norris is, or had been, a distributary of the Lemon when the Lemon was at a higher level. This condition undoubtedly caused ice from the accumulation area of the Lemon Creek to increase the volume of ice in the Norris.

Unfortunately the accumulation in the Lemon Creek area and its partial distribution through the "Dead Arm" could not explain an increase in the Norris of the magnitude noted. An explanation would have to point out a condition, such as a shift in centers of accumulation, which would affect the Norris in its main accumulation areas around Guardian Peak and "Death Valley" without affecting other nearby accumulation areas for other glaciers.

Trimlines of the Taku Glacier at Low Level

Personnel: R. L. Pierce, A. P. Muntz

Equipment: Increment borers, aneriod altimeter, aerial photos.

Taku Lodge Area:

One day was spent obtaining cores and counting rings on recently cut stumps from the spruce forest which occurs on the tide flat surrounding Taku Lodge. These have not been fully analyzed, but ring counts on stumps gave an approximate age for this forest of 85 years.

An attempt was made to determine the manner of formation of the level area around Taku Lodge by studying several profiles cut to a depth of 14 feet along the east bank of Taku River south of the lodge. The profiles revealed a regularity of formation in which strata were made up of bands of pebbles up to 30 mm. in particle size, medium and fine sand strata, and bands of variously sized gravels alternating indiscriminately with one another. The lack of uniformity in the size of the constituent material of the different sediment bands and the haphazard alternation of different bands seemed to preclude the possibility of lake deposition as an explanation for the origin of the area. The regularity of the strata suggests deposition of material by tidal action and it was assumed by the investigators that the area was an old tide flat. Several irregular surface features in the interior of this tidal flat probably represent the remnants of tidal inlets and levees. The few boulders present probably represent ice-rafted deposits.

Taku Point Area:

The level area which begins one mile south of Taku Point and continues for a distance of two miles was found to be a tidal flat with much of the area still in the early stages of formation. Profiles revealed a regularity of deposition, but a lack of uniformity in the size of constituent material of one stratum compared with another. From the surface to a depth of two feet four separate layers of organic material occurred. The layers probably represent debris deposited on the tidal flat during earlier stages of its formation rather than deposition *in situ* upon established vegetation.

Two stands of young spruce forest which occur on this tide flat were investigated and cores removed from the larger trees. The stand located one mile south of Taku Point was estimated to be 80 years old. The stand located two miles south of Taku Point was estimated to be 125 years old. If either stand was located on an old moraine or the position of an old moraine then that moraine must have been destroyed or obscured by tidal action for no evidence of a moraine is apparent.

Taku Glacier Trimlines on Norris Ridge:

A moraine of Taku Glacier is located approximately 500 feet above the present edge of the ice on the northeast and east slopes of Norris Ridge above the present terminus of the Taku. This moraine extends for a distance of one mile along the ridge and curves around the east tip of the ridge where it dissappears before intersecting moraines from the Norris. The moraine was followed in an attempt to find trees tilted during formation of the moraine. All trees cored above and below the moraine were found to be under 200 years of age with no evidence that they had existed prior to formation of the moraine. Because of the massive size of these trees, 3-4 feet d.b.h., it was almost impossible to obtain cores from the center of the trees. Previous use of an extension had resulted in loss of one of the increment borers.

The fact that only trees under 200 years of age could be found above and below the moraine led to the consideration of a possibility that an impounded lake was formed during the Taku maximum on top of Norris Ridge which is today represented by an extensive muskeg.* The stream which drained this lake flows down the east tip of Norris Ridge at the top of which it has cut a narrow gorge through solid bed rock.

According to Post and Nielsen another moraine of the Taku is present on Norris Ridge approximately one mile above the present terminus of the glacier and at a lower elevation than the moraine that was investigated. Insufficient time was available to make an investigation of this lower moraine.

Cores collected on this trip have not been analyzed, nor have altimeter readings been adjusted to final form.

Low Level Trimline of the Lemon Creek Glacier

Personnel: R. L. Pierce, Warren Asa

An attempt to determine whether or not the situation found to exist on the Norris was also true of the Lemon Creek Glacier was unsuccessful. The party attempting to investigate the terminus was caught in a storm during the first night away from Camp 16A and physical discomfort caused plans for the investigation to be abandoned before reconnaissance observations could be made. The probability exists that the supposition of a recent advance for the Lemon is well founded as earlier investigators have not found any evidence of a 200-year old maximum, but this is a supposition that will need confirmation by actual investigation of the terminal region of this glacier.

*Note: Today two small lakes and a swamp exist in this supposedly inundated area.

V. GEOBOTANICAL WORK

A. P. Muntz

The geobotanical research program which was to have been undertaken during the 1953 JIRP field season unfortunately could not be carried out as planned because of the lack of personnel. One member of the proposed geobotanical group failed to participate in the summer's work, and Richard Pierce and Philip Muntz, the other members of the group, were unable to work together on the problem of the late postglacial maximum of the Juneau Ice Field until the closing weeks of the season, when the general area of the Norris and Taku termini was studied.

This report will endeavor to summarize the results of the investigations in this area in some detail, but no attempt will be made to describe the summer's activities as a whole. It is considered that such tasks as excavating and repairing "weasels", packing supplies, and constructing stone shelters require no description.

A brief discussion of problems recognized in the Lemon Creek Glacier area is also included.

Lemon Creek Glacier

The field work accomplished in the Lemon Creek Glacier area permitted no more than the recognition of a number of problems. The most obvious of these was unquestionably concerned with the weather - dense fogs, high winds, and heavy rains all too frequently made field work impossible.

One of the most significant of the problems in this area is that concerned with the recent maximum advance of the Lemon Creek Glacier and its neighbor Ptarmigan Glacier. It remains to be determined if these glaciers were affected by such a maximum. Although a comparison of the present terminus of Lemon Creek Glacier with the 1948 terminus as shown on air photos of that date reveals that the glacier is retreating, and high trimlines along the flanks of the upper Lemon also indicate a higher ice level relatively recently, very little is known of how far the glacier advanced down Lemon Creek canyon toward Gastineau Channel. Obviously, this should be determined before the fluctuations of Lemon Creek Glacier can be compared with those of the other glaciers of the Juneau Ice Field.

The extreme steepness of the upper Lemon canyon makes field work in the area difficult, and has probably also resulted in the destruction of any terminal moraines which might once have existed. The great depth of this water-cut canyon suggests that no major advance of the ice into the wider valley below has occurred in at least several thousand years, but the rate of erosion by debris-laden

meltwater streams is so variable and so little understood that such a conclusion can only be regarded as guesswork.

Since well-defined end moraines are present below the terminus of the Ptarmigan Glacier, investigations of these moraines and associated trimlines should contribute significantly to an understanding of the recent movements of the Ptarmigan, and indirectly, possibly those of the Lemon also. The valley of Ptarmigan Creek, below the present terminus but above the ice of Lemon Creek Glacier, contains, in addition to the moraines, a number of terraces on the west wall of the valley, composed largely of sorted gravels. Detailed mapping of these terraces is probably also essential to an understanding of the recent glaciation of the valley.

The presence of two narrow, stream-cut trenches in the lower Ptarmigan Valley, the deeper of which is now occupied by the stream, indicates that a shift in the stream course has occurred. The significance of the diversion is unknown - possibly it can be related to an advance of the Ptarmigan down the valley or possibly by the Lemon up the valley. The depth of the stream-cut gorge through which Ptarmigan Creek now flows suggests that considerable time has elapsed since Ptarmigan Glacier was an active tributary of the Lemon.*

Two moraines which occur in a most unlikely position near what appears to be the head of Lemon Creek Glacier deserve detailed study. Actually the location of these moraines is not as enigmatic as casual observation suggests. They were obviously formed by a glacier which although in contact with the ice of the Lemon along a sub-glacial divide, flowed south toward the Salmon Creek watershed, as it still does at present. The stream which now flows from the terminus of the glacier eventually enters Salmon Creek Reservoir.

Both moraines are well defined, especially the innermost. The outer is obviously a great deal older, however, since the boulders it contains are well weathered, in places so completely that a considerable amount of soil has formed. The outer moraine also supports much more vegetation. If the age of these moraines could be determined and correlated to those of the Ptarmigan, a great deal of progress would have been made toward an understanding of the recent fluctuations of cirque glaciers in the Juneau area.

Lower Norris and Taku Glaciers

Although it is apparent that the Taku and Norris Glaciers are at present behaving quite differently - the Taku advancing rapidly, and the Norris retreating, we have no reason to believe that this has always been the case. In fact, it has been suggested that the present discord in the movements of the two glaciers is abnormal, and a recent phenomenon, and that formerly these fluctuations were similar. A careful, thorough study of the trimlines along the lower Norris and Taku should be most helpful in establishing such a former

*Note: A U.S.G.S. report states the Lemon Creek and Ptarmigan Glaciers were joined in 1910, but this summer's work throws doubt on this statement.

correlation, or conversely, in disproving it.

Although a complete study of the Norris-Taku trimlines was not possible, and the results of the work so far accomplished do not permit final conclusions as to the recent movements of these glaciers, certain facts which appear to be of considerable significance were established, and inevitably, a host of problems whose solution must depend on further detailed field work were recognized.

Norris Glacier

From a base camp at "Glory" Lake (officially unnamed) on the southern side of the lower Norris, approximately one and one-half miles from the terminus, the forest trimlines on both the north and south sides of the Norris were investigated. In addition to these ice-trimmed lines above the flanks of the glacier, a high water level at Glory Lake, marked by an extremely clear line between large conifers and small alders and spruces, was also studied.

Although the first crossing of the lower Norris from the Glory Lake base camp to the north wall of the glacier where Bed Rock Camp was established was difficult, the locating and marking of a route by Austin Post made subsequent crossings much less arduous. It is suggested, however, that future investigators concerned with the Norris Ridge area between the lower Norris and Taku establish their base camp on the ridge itself, rather than at Glory Lake. The ridge is easily accessible by small boat at high tide at the present time although shifts in the courses of meltwater streams from both the Norris and Taku apparently occur frequently and could make direct approach by boat impossible.

Trimlines Above the North Side of the Lower Norris

The rock wall which confines the ice on the northern side of the lower Norris shows with remarkable clarity the recent fluctuations in height which the ice has undergone. Exposed bedrock which has been rounded and polished, masses of loose boulders, finer material, and scarred and broken tree trunks that have been plastered onto the bedrock surface, and clearly defined belts of lateral moraine all indicate higher levels of ice.

Less obvious than the simple fact that the ice stood higher, but nevertheless apparent, are the indications of the lengths of time which have elapsed since the higher levels were reached. Clearly defined zones of vegetation in varying stages of development are the most readily observable indices of the age of the various maxima, although these are in many cases confused and complicated by factors other than those directly associated with the ice.

Six generally distinct zones of vegetation, including the old forest near the summit of the ridge and bare rock immediately above the

present ice level, may be observed on the steep slopes above Bedrock Camp.

The lower zone, (1) without plants, was obviously freed from ice during the present summer. In some places, huge blocks of ice buried under debris still persist in this zone, and masses of rock flour still blanket much of the coarser material.

In zone 2, scattered plants (mainly fireweed) have established themselves. Much of the extremely fine rock flour has been washed off this surface, although the sparse plant cover and fresh till indicate that the ice cover persisted here until probably as late as 1952 or 1951. Since there is no clear boundary between this zone and the next, in which very small alders occur, these are considered as one.

In the third zone, small alders and fireweed are abundant, forming, where slope and soil permit, an almost continuous cover. Although there seems to be no clear line of separation between zones two and three, there can be no doubt that the latter has been free of ice for a longer period than that immediately below. However, all the zones so far described are indicative of very recent deglaciation only, and the differences observable on these lower slopes represent minor recent variations in the last major recession, still in progress.

The fourth and fifth zones are similar except that the trees of the fifth zone, especially the spruces, are considerably larger than those of the fourth. In both, however, alders of large size are abundant, and a considerable amount of organic material has accumulated under the trees. The spruces in zone 4 are little more than seedlings, but in zone 5, a ten-inch spruce was cored (Core 1) and several other trees at least this large were also observed.[1] Core 1 indicated a tree approximately 23-24 years old, and Core 2, also taken from a spruce in zone 5, contained approximately 34 annual rings. Although a fairly well-defined moraine occurs between zones 3 and 4, the best developed moraine on the entire slope is found at the upper limit of zone 5. Large boulders, broken stumps, and smashed trees form an obvious boundary between the young forest below and the ancient one above.

Within the old forest, previously referred to as zone 6, a core taken from a very large spruce (Core 3) showed the tree to be probably older than 250 years. Because of a rotten center, even a rough field estimate of the age of this spruce was difficult to obtain. The tree from which Core 3 was taken, located only a few feet above the moraine already mentioned, is part of an old forest apparently well over 200 years old, which extends along the top of Norris

[1]Ages of trees estimated from annual ring counts in the field should be regarded as tentative. Laboratory analysis of the cores and sections described in this report is being carried out at the University of Minnesota, Department of Botany.

Ridge until interrupted by muskeg on the summit.

The transition form zone 5 to zone 6, therefore, is extremely abrupt - from a young forest of large alders, and small spruce and hemlocks approximately 30 ± 10 years old, to an old forest containing yellow cedar, hemlock and spruces well over 200 years old, with a floor littered with rotten logs and stumps. There is at this place no forest intermediate in age between these two extremes which would suggest an ice maximum approximately 210 years ago.

If the Norris Glacier reached the level indicated by the moraine above zone 5 at some time in the 18th century, then it must have reached that same level again in the early years of the present century. There is no evidence of such an 18th century advance on the Norris itself, however, and it appears that the Norris ice stood higher in the first few years of the 20th century than it has in well over 200 years. The 200-year maximum recognized elsewhere on the Juneau Ice Field, if present on the Norris, has been overridden by a much later (1900 ± 20) maximum.

Further east, immediately above the present terminus of the Norris, the situation is complicated by a trimline and moraine formed by the Taku Glacier at a much earlier time. This trimline must be crossed by that of the Norris, although the area where this must have occurred is so steep that it is unlikely that it can be accurately located. The early 20th century trimline of the Norris, however, can be traced down past the present terminus, to the largest, outermost terminal moraine in front of the glacier.

Trimlines Above the South Side of the Lower Norris

The results of the investigations above the north flank of the lower Norris needed confirmation, or contradiction, by similar work on the south wall. Consequently, by working from the Glory Lake base, trimlines east and west of the lake were studied.

Glory Lake lies in a steep, U-shaped valley which obviously contained a glacier tributary to the Norris at some remote period, probably during Wisconsin time. The lake appears now to be dammed by a moraine, although the present outlet is over bedrock. Between the lake and the Norris ice, a series of moraines reveal former stands of ice. The largest and, of course, oldest of these is the outermost, standing within a few feet of the present shoreline of the lake. It seems probable that this moraine represents the maximum recent advance of the Norris ice into this tributary valley, since well-weathered talus slopes just beyond the front of this moraine suggest that the ice did not advance past this point for a considerable length of time. Additional evidence supporting this view is the fact that the moraine can be traced up the northwest side of the tributary valley onto the wall of the Norris trench itself, where it is clearly the uppermost moraine which can be recognized.

Although the boulders included within the moraine above and west of Glory Lake appear to be discolored and almost all the fine material washed away, and numerous large alders and other trees are established on it, a core from one of the largest spruces on the moraine (Core 8) indicated the tree to be only thirty years old. A section from the largest willow found on the moraine showed the tree to be approximately twenty-five years old, and another from a large alder indicated an age of about forty years.

On the outer side of the moraine, both swampy meadows and old forest were observed. A core from a large spruce (Core 9) near the front of the moraine failed to reach the center of the tree but well over 200 rings were counted in the section obtained. Again large, rotten stumps and trunks suggested a very old forest. As on the north side of the Norris, there was no belt of first-generation forest to suggest a high ice level during the mid-eighteenth century, and the conclusion must be drawn that the maximum which occurred at the beginning of the present century reached a level as high or higher on the valley walls than did the "200-year maximum", if the latter actually did occur on the Norris.

Further corroboration of this conclusion was obtained when the trimline and moraine on the south wall east of the Glory Lake Valley were examined. The lower portion of the slope, below the highest moraine and trimline, showed evidence of successive stages of deglaciation from freshly exposed bare rock near the ice to small spruces and dense alder growth near the highest moraine. From a very large spruce a few feet above this well-defined moraine, a core containing roughly 300 ± 50 annual rings was taken (Core 10), confirming that the forest pre-dated the mid-eighteenth century.

This moraine could not be followed east along the south wall of the Norris Valley to the terminus because of the extreme steepness of the slope. Near the present terminus, however, the slope becomes much less steep and the moraine again is clearly defined. It was in this area that the most positive dating of the moraine was possible. Several pushed trees were discovered, and sections obtained from two of them. Both these trees (a yellow cedar and a hemlock) had been knocked over by trees which were uprooted by the ice and incorporated into the moraine. The cedar was discovered lying on a dead log which was imbedded in the moraine, and under another log, also partially covered by moraine. Laboratory analysis of the growth rings of these trees should date the moraine very closely. A rough field estimate indicated that both the cedar and hemlock were pushed over approximately 40 ± 10 years ago. A spruce growing on the moraine near the pushed trees (Core 19) was found to be approximately thirty years old. By establishing the age of the highest advance in this area at roughly forty years, the work therefore confirmed the results obtained in the other investigation along the flanks of the Norris.

Glory Lake Trimlines

The water-trimmed forest line above Glory Lake presents an enigma whose solution might clarify the general problem of the recent major fluctuations of the Norris Glacier.

Between the present lake surface and the edge of the forest above, there is a broad belt in which trees are absent. Since the ice of the Norris must have dammed the valley in the early years of the present century, this lack of living trees is not surprising, but the absence of standing, water-killed trees or stumps in the belt cannot easily be explained, unless one assumes that the ice dam indicated by the large moraine along the north shore of the lake persisted for a very long period of time. If we assume that the Norris ice advanced into the tributary valley during the eighteenth century, dammed the lake to the height of the forest trimline, and then retreated, lowering the lake level, it would be reasonable to believe that a forest would have become established below this trimline before the early twentieth century maximum was reached.* The fact that there is no evidence of such a forest suggests that little, if any, retreat occurred between these two advances, and that perhaps the level of the Norris ice remained almost constant for over 150 years. On the other hand, if there was no 200-year maximum on the Norris, and the advance of the early twentieth century ice dammed the lake and killed the trees, then the absence of dead trees is even more inexplicable. The only possible explanation appears to be that the lake must have been dammed to the high level indicated by the trimline for a long period of time (sufficiently long to permit the complete destruction of a drowned forest) and that this high level of the lake persisted until the present century. Whether or not this actually was the case is unknown, but further investigations of the problem might provide the answer. The remote possibility that the valley was recently glaciated should not be overlooked, however improbable it may appear.

Norris Terminus

Reconnaissance of the sand and gravel flats between the terminus of the Norris and Taku Inlet failed to reveal any terminal or recessional moraines other than those close to the present ice front. The outermost of these was traced up onto the side of the Norris Valley, and was found to be the same moraine in which the pushed cedar and hemlock were found.

Cores were taken from several trees in the southernmost of the forested areas on the flats, and although the trees were of a very large size, none over 200 years of age were discovered, and the appearance of the forest also suggested that it was first generation.

*Note: Mr. William O. Field, Jr., has evidence that Glory Lake was ice-dammed as recently as 1926.

Conclusion

Since the highest trimlines on the valley walls of both sides of the Norris Glacier were found to have been formed during the early part of the present century, and lateral moraines formed by the ice along these trimlines were traced down to the large end moraine near (1/4-1/2 mile) the present terminus there seems no reason to believe that the Norris Glacier has independently advanced further or stood higher in the last 200-250 years than it did during the most recent maximum at the beginning of the present century.

Taku Glacier

The lower Taku area unfortunately was not thoroughly studied. Work was limited to the Norris Ridge area, and a great deal more remains to be done before the recent fluctuations of the Taku are even generally understood.

Reconnaissance of the Norris Ridge area resulted in the discovery of an old moraine of the Taku more than 450 feet above the sandy outwash between the present termini of the Norris and Taku. (This elevation was recorded near the point where the moraine crosses a stream which runs southeast from the ridge to the outwash plain.) Fortunately parts of this moraine are very well defined topographically, making its recognition possible. Since there appears to be little difference in the forest on either side of the moraine, and huge trees with diameters of more than four feet were found growing both on the moraine and below it, casual observation of forest conditions could not here indicate the former ice line. However, cores taken from the largest spruces found on the moraine indicated an age of less than 200 years, in spite of their great size (Cores 36 and 37).

Although more trees on both sides of the moraine should be cored, the work already done strongly suggests that the line of this moraine represents the maximum recent advance of the Taku, and that it occurred roughly 200 ± 50 years ago.

This moraine was followed south along the ridge toward the Norris Glacier as far as possible. On the south side of the stream mentioned above, the moraine becomes much less clearly defined, and still further south, its position is indicated only by a few boulders. Perhaps this is due to the increasing steepness of slope; whatever the reason, the moraine could not be followed all the way to the highest trimline of the Norris. In the distance the moraine was followed, it was observed to be descending slowly. At the point when it was last recognized, almost directly above the present terminus of the Norris, it was still more than 400 feet above the outwash plain. If we project the line further south and allow for a decrease in elevation similar to that observed where the moraine was well defined (very roughly 50 feet per one-half mile) then this line should appear on the side of the valley south of the Norris terminus approximately 275 feet above the sandy outwash plain. Although there is no reason

to assume that the line would continue to descend at a uniform rate, it is not difficult to imagine a swollen Taku advancing to the Norris, which then became a tributary, and continuing past the Norris Valley toward the south.

If this did occur, then some evidence of the high ice level should exist on the slopes overlooking the outwash plain south of the Norris terminus. Although this area was investigated, no clear proof of a maximum occurring roughly 200 years ago was discovered. However, the absence of post-first generation forest on the lower part of the slope suggests that such a maximum might have occurred. Cores taken from two large spruces here (Cores 20A and B) both indicated ages of less than 200 years. No clear line between the older forest above and the younger one below could be found, however, in spite of the obvious differences that exist between the forest on the upper slopes and that on the lower.

No indication of a moraine was found in the area, but the nature of parts of the old moraine on Norris Ridge already described suggests that this does not prove the absence of a high ice level. It is possible that additional field work in the area would yield significant results. Forest conditions seem to indicate that a trimline does exist here, and careful detailed study might locate it. If, on the other hand, the trimline does not exist, and the differences in forest development are due to other factors, further work should be able to determine this also.

Conclusion

Work on the Norris Ridge area established the fact that roughly 200 ± 50 years ago, Taku Glacier stood high above its present level, approximately 400 feet above the outwash plain of today. Obviously the terminus of the glacier then stood far beyond its present position, but the location is unknown. Forest conditions on the lower slopes of the trench in which Taku Inlet lies, south of the Norris terminus and above the outwash plain suggest that the Taku, with the Norris as a tributary, trimmed the forest along these lower slopes as it advanced to an unknown point in the valley to the south, but additional field work in the area will be necessary before definite conclusions can be reached.

Eastern Shore of Taku Inlet

The height of the 200 ± 50 year maximum on the southwest wall of the Taku indicates that the glacier must at that time have advanced far out into the inlet, perhaps reaching the opposite shore and possibly damming the Taku River, forming a lake as suggested by Lawrence.[2] It was hoped that work on the eastern side of the inlet

[2] D. B. Lawrence: Glacier Fluctuation for Six Centuries in Southeastern Alaska and its Relation to Solar Activity, Geogr. Rev., Vol. 40, 1950, p. 209.

above and below Taku Point would reveal some evidence of former glaciation and events associated with it.

Vicinity of Taku Lodge

The generally flat area which borders the eastern shore of Taku River south of Taku Lodge was investigated with the hope that evidence for or against a former lake bed would be discovered.

Since the Taku River is now actively cutting into the steep bank which forms the shoreline below the Lodge, many excellent exposures of the material composing these flats are visible. These exposures indicate that the material is well stratified, although some of it is so coarse that it is difficult to imagine how it could have been carried far out into the still waters of a lake to form a thin, well-sorted layer containing pebbles up to two inches in diameter. Although ice rafting certainly could account for the transportation of coarse material out into the lake, it does not explain the formation of a continuous, well-sorted band of rounded to sub-angular pebbles.

Sand, sorted into layers of varying fineness, constitutes most of the material underlying the surface of the plain. The individual strata appear to be nearly horizontal and are continuous over long distances. There is a suggestion of a slight dip toward the south, although this is by no means certain.

The surface of the flats is not as even as a view from the river suggests; very low, narrow, winding ridges are frequently encountered, and are most abundant and best developed in the southern portion of the plain. Although neither the large gravels nor the irregular surface features indicate deposits laid down in a deep, quiet lake, they do not eliminate the possibility that a lake did exist here. Since most ice-dammed lakes are subject to sudden, violent draining, the rapid fluctuations of water level accompanying such drainings might produce lake bottom phenomena similar to those described.

Two areas with similar topographic and structural features were investigated south of Taku Point (approximately 2-1/4 and 3-1/2 miles south). Both are covered with a youthful forest, as is the area below Taku Lodge. Exposures along the tidal front of the northernmost of these flats were found to be almost identical to those observed below the Lodge, suggesting a similar origin for both.

It is extremely difficult, however, if not impossible, to visualize how these flats, well south of Taku Point, could have been formed in a lake. This permits two possible conslusions: (1) the flats north and south of Taku Point have a similar origin and therefore are not the result of deposition in an ice-dammed lake, or (2) although similar in appearance and structure, their origins are not the same, and those above Taku Point might be lake deposits.

So similar are the described deposits north and south of Taku Point that it is difficult to escape the conclusion that they have a common origin. The nature of their origin, however, if it is the same, cannot easily be determined. It is possible that they were formed when the sea stood higher relative to the land than it does at present, a condition which might also explain the "scoured" appearance of the rocks above the present tide level in the inlet. Since a good deal of evidence has been compiled which indicates that large parts of the coast of southeast Alaska are recently emergent,[3] the possibility deserves careful consideration.

If the alternative that the deposits are not similar in origin is accepted, and we assume that Taku Glacier did advance across the Inlet to Taku Point, then of course there is a possibility that a lake was formed above the Point. It is hardly necessary to point out, however, that Taku Glacier could have advanced across the Inlet without damming Taku River, and that evidence of ice cover on Taku Point alone does not prove the former existence of a lake.

If we assume that Taku Point was glaciated during the advance of Taku Glacier which apparently occurred in the latter part of the eighteenth century, we are faced with the problem of how high the ice stood on the east wall of the inlet, and how far down the inlet the ice advanced. Below Taku Point, the rock walls up to approximately 100 feet above tidewater appear to be recently scoured and support only low, gnarled trees. However, a section from a stunted spruce growing in a rock chimney a short distance south of U. S. Coast and Geodetic Station LIP (located about 5/8 mile below Taku Point) showed the tree to be very old - a rough field count indicated an age of 220 years. The elevation of this tree was not determined, but it was well within the zone which appears scoured and certainly less than 150 feet above tidewater.

This suggests (1) that the so-called 200-year advance occurred considerably more than 200 years ago, or (2) that the line of maximum 200-year advance lies somewhere between Taku Point and the LIP Station, or (3) that the ice was so thin below the station that it did not reach the level of the spruce described, and therefore the terminus must have been very close to that point. The possibility that the scoured appearance of these slopes may be due to wave work during a time of higher sea level also deserves consideration.

No evidence of any moraine was discovered south of Taku Point. The two areas which Lawrence cites as possible moraines in his paper previously mentioned (page 208) are actually well-stratified alluvial or marine deposits.

[3] W. S. Twenhofel, "Recent Shoreline Changes along the Pacific Coast of Alaska", <u>Amer. Jour. of Sci.</u>, Vol. 250, July 1952, pp. 523-48.

Conclusion

The recent geomorphic history of the Taku Inlet-River Valley area in the vicinity of Norris, Taku, Hole-in-the-Wall, and Twin Glaciers presents a variety of problems, most of which are intrinsically associated with the recent fluctuations of these glaciers. One of the most interesting of these concerns the possible existence of an ice-dammed lake in the Taku Valley north of Taku Point. Although sufficient evidence to permit final conclusions on the question of the lake is not yet available, most of the observations made appear to support a negative view. It seems probable that recent changes of sea level have been of considerable significance in the area, and a knowledge of these fluctuations seems essential to the solution of the lake problem as well as to an understanding of the general recent physiographic history of the area, including the recent maximum advances of the several glaciers in the vicinity.

VI. SURVEYING PROGRAM

Austin S. Post

Objectives and Scope

1. To determine the movement of the Taku, Norris and Lemon Creek Glaciers at selected points.

2. To extend the triangulation into previously unexamined portions of the ice field.

3. To compile a topographic map of the Lemon Creek Glacier, contour interval 100 feet.

In connection with the above program it was further planned to:

a. make complete photographic panoramas from all major triangulation stations, and photograph various other glacial features of the ice field.
b. place permanent reference marks from which future vertical thickening or ablation of the glaciers could be easily determined.
c. co-operate in every possible way with the various other phases of the research program.

Summary of Accomplishments

Movement Program

Taku Glacier: extensive and complete. Results presumed good.
Norris Glacier: abandoned.
Lemon Creek Glacier: much reduced, results undetermined.

Triangulation

A new line was run in from Taku Inlet to Lemon Creek Glacier. Four widely separated triangulation stations were occupied for the first time. Sixteen lesser stations were occupied. Results presumed good.

Topographic Map, Lemon Creek Glacier: not started.

Photography

Panoramas were taken from five important triangulation stations. Many other photo stations were occupied. Various features of scientific interest were photographed. Results good.

Reference Marks

Several were placed at selected points along the margins of the Taku and Norris Glaciers.

General Description

Movement Program

The methods used to determine the direction and velocity of the surface movement of the glaciers were similiar to those used by the 1952 field party. Briefly, these consist of setting up tripods over selected locations on the glacier (see end of this section) and determining their position at intervals by use of instruments, a measured base line and two widely separated triangualtion stations located on nearby rocky points overlooking the glacier. A Wild T2 theodolite was used to determine the horizontal and vertical angles.

Taku Glacier

Here the movement program was extensive consisting of four transverse rows of tripods totaling thirty-nine in number, located as follows:

Seismic Profile No. 1 (about two miles above the terminus)
- 12 tripods transversely across the glacier
- 3 tripods longitudinally near the center of the glacier

Seismic Profile No. 2 (near "Columbia Basin")
- 6 tripods transversely across the glacier 1½ miles below "Columbia Basin"
- 9 tripods transversely across the glacier on the location of Seismic Profile No. 2
- 3 tripods located longitudinally near the center of the glacier

Seismic Profile No. 4 (Camp 10)
- 5 tripods transversely across the glacier
- 1 tripod longitudinally near the center of the glacier

Transverse Profiles were made with the stadia rod on Profiles 2 and 4, and several positions were established between Profiles 2 and 4 from which a longitudinal profile could be made between those points.

Triangulation Stations used in connection with this program were as follows:

Seismic Profile No. 1
- Station No. 1. (both located on eastern wall of Taku valley
- Station No. 2. 300 and 500 feet respectively above the glacier)

Seismic Profile No. 2
- North Cairn, "Goat Ridge" (200 feet above glacier)
- South Cairn, "Goat Ridge" (500 feet above glacier; 2655 feet south)

Seismic Profile No. 4 (Camp 10)
- Station 19-A (4 feet south of Station 19)
- Station Taku-A1 (100 feet above glacier N.W. slope Taku A)

Lemon Creek Glacier

Due to unforeseen delays the extensive program outlined for this glacier had to be greatly reduced and only late in the season were movement tripods set up, consisting of:

5 tripods transversely across the glacier about one half mile below Camp 16-A
2 tripods longitudinally near the center of the glacier
4 tripods transversely across the glacier about 1½ mile below Camp 16-A

Triangulation Stations used in connection with this program were:

Station "Vesper"
Station "Alto"

Norris Glacier

Tripod building materials were air-dropped for movement studies to be made at a campsite about 10 miles up Norris Glacier. Due to unavoidable delays and inaccessibility, it was found necessary to abandon this project.

Triangulation

A total of 20 triangulation stations were occupied during the course of the season as follows:

New stations; complete sets of readings:
Station "Snowdrift" 6100 ± feet (2½ miles west of "Project Peak")
Station "Ogilvie" 7700 ± feet (Canadian, U.S. Boundary Peak 96)
Station "Thoroughfare" 3773 ± feet (4 miles southwest of Station Norris)
Station "Observation" 4960 feet (one mile east of Station Cairn)

New or reoccupied stations, additional readings:
Station "Cairn" 4506 ± feet (southwest side Lemon Creek Glacier)
Station "Norris" 4144 feet (Station 14-A)
Station "Newt" - sea level - (U.S. Coast and Geodetic Survey Topo. Station)
Station 19 (Camp 10)
Station Camp 15

New stations, secondary, to determine geographical position:
Station Photo Station "A" Norris Glacier
Station Photo Station "B" Norris Glacier
Station Photo Station "F" Norris Glacier

New stations, (movement program):
- Station 1
- Station 2
- Station "North Cairn"
- Station "South Cairn"
- Station 19-A
- Station "Taku A-1"
- Station "Vesper"
- Station "Alto"

Topographic Map, Lemon Creek Glacier

Illness, and subsequent commitments delayed this project until late in the season when an alidade, plane table and two stadia rods were in readiness to begin this work. Continuously unfavorable weather forestalled all efforts to begin this important job at this point, and the project had to be abandoned.

Photography

Panoramas from five important triangulation stations were made, various existing photo stations were re-occupied, and several new photo stations were established, as follows:

Photo Station "E", Taku Glacier. Located on rock 100 feet from point where glacier reaches tide, north side. Ice-tree contact. Occupied twice during season.

Photo Station "F", Norris Glacier. Located 100 feet above glacier near southeast-most point of terminus. Views of trimlines, up-glacier, across terminus, west margin Taku Glacier and central front Taku Glacier.

Photo Station "G", Norris Glacier, near "Glory Lake." Located on rocks 100 feet above point where "Glory Lake" stream enters Norris Glacier. Views of "Glory Lake," trimlines, up Norris Glacier and the great "Glory Hole" a short distance north on glacier from stream.

Other Photos. Many dozens of views of glacial and geological features were photographed. Complete lists and descriptions are being compiled.

Ice Level Reference Marks

These stations are marked by cairns, and/or yellow paint. Generally a large, conspicuous "1953" painted on a rock locates station; other marks are located near by.

Taku Glacier, Seismic Profile No. 1.
East Side. Paint marks established 0 feet and 60 feet above margin of glacier on cliffs a short distance up valley from Station No. 1.

West Side. Paint marks 10 feet and 30 feet above ice, on cliffs, first sheer rock walls, about 2 miles above terminus.

Taku Glacier, "Goat Ridge" (Seismic Profile No. 2).
East side glacier, west portion of northern most point "Goat Ridge" on rock-ice contact. Visible from margin of glacier or ridge crest.

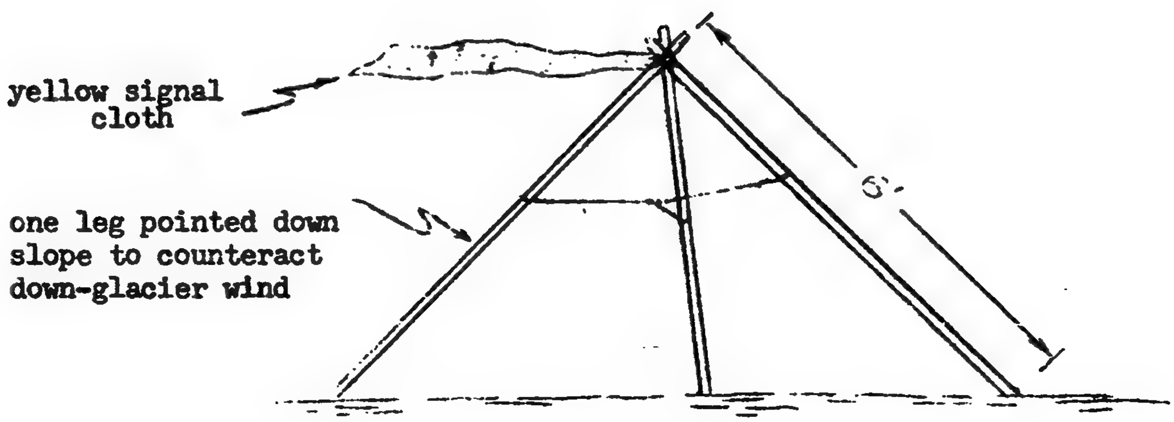
Taku Glacier, Seismic Profile No. 4 (Camp 10).
Cairn located 150 feet above glacier and west from Camp 10, marked with paint. Theodolite Station. Stadia distances and elevations at various points on glacier.

Taku Glacier, "icefall" 1 mile north of Camp 10.
3 cairns marked with green paint situated on ice-rock contact along top of nunatak.

Norris Glacier.
"Glory Lake," (southwest side) one mile above terminus.
Paint marks on rock 0 feet and 30 feet above ice, 300 feet west from point where "Glory Stream" enters Norris Glacier.

"Bedrock Camp," (northeast side) one mile above terminus.
Paint marks on rocks 0 feet and 30 feet above ice. Visible from margin of glacier.

Ptarmigan Glacier, terminus.
Yellow paint marks on conspicuous boulder 20 feet north from ice, 1953.



Poles consist of alder sticks or milled 1 x 1½ inch wood from local lumber yard preferred as they are much lighter and easier to transport. Legs should be well spread at an angle of not less than 45° from the vertical. Wire should be brought to center from each leg and tied in such a way to prevent its slipping.

Tripods set up in this way stood remarkably well during many weeks of heavy wind. Fluttering cloth greatly aids in locating distant tripods.

VII. SCIENTIFIC WORK ACCOMPLISHED

1. Fifteen tripods were set up on the First Seismic Profile two miles from the terminus of Taku Glacier and the amount and direction of their movement were measured.

2. Eighteen tripods were set up on the Second Seismic Profile ten miles from the terminus of Taku Glacier, and their movement was measured.

3. Six tripods were set upon the Fourth Seismic Profile sixteen miles up Taku Glacier, and their movement was measured.

4. The aluminum pipe in the ice at Camp 10B was found, and its movement during the past year was again determined.

5. A snow survey was made over nearly the entire Taku system. The depth and density of the snow cover were measured.

6. Snow pits were dug at Camps 10A, 10B, and 9B. Depth, density, and stratigraphy of the snow cover were measured. At Camp 10B the pit was dug through the 1951-1952 snow cover as well as the 1952-1953 cover.

7. The present level of the ice along Taku Glacier was marked at various points by paint markers on the rock walls. These are to be used for indicating future changes in the thickness of the ice and should be useful aids in predicting future advances or retreats of the glacier.

8. Ablation measurements were made on the snow at Camp 10A, sixteen miles up Taku Glacier.

9. Meteorological measurements were made at the Research Station (Camp 10) from the middle of June to the middle of August.

10. The slope of the surface of the ice was measured on Seismic Profiles Nos. 1, 2, and 4. Transverse topographic profiles were also made at these locations.

11. The position of the firn line throughout the season was determined for Taku, Norris, Lemon Creek and Ptarmigan Glaciers.

12. The amount of ablation (vertical melting) of the ice near the terminus of Mendenhall Glacier was measured.

13. Ten tripods in two lines across Lemon Creek Glacier were used to determine the amount of movement of the ice of this glacier.

14. The depth, density, and distribution of the snow cover were determined on Lemon Creek and Ptarmigan Glaciers.

15. Ablation measurements were made on the snow of Lemon Creek Glacier.

16. An extensive micrometeorological program was carried out on the center of Lemon Creek Glacier. Measurements included the temperature gradients in the air near the surface, amount of energy received from the sun, importance of eddy diffusion in bringing about ablation, and the amount of condensation of water vapor from the air onto the snow surface.

17. Mt. Snowdrift and Mt. Ogilvie;(on U. S.-Canadian Boundary) were occupied as triangulation stations. These extend the surveys to the western and northern parts of the ice field and tie in the J.I.R.P. surveys with those of the International Boundary Commission.

18. Glory Mt. was occupied and Norris Peak reoccupied as triangulation stations in the southwest part of the ice field.

19. Observation Peak and Cairn Peak were occupied as triangulation stations to tie in Lemon Creek Glacier with the rest of the Juneau ice field.

20. The Coast and Geodetic Station Newt on the Norris Glacier tidal flats was used as a triangulation station to bring in a new survey line from tide water.

21. The photo stations near the terminus of the Norris Glacier were reoccupied and their position determined by triangulation. The 1953 position of the ice fronts of the Norris and Taku Glaciers was partially surveyed.

22. The location of the snow divide between Taku and Mendenhall Glaciers, Taku and Eagle, Taku and Herbert, Taku and Talsekwe, and Taku and Llewellyn Glaciers was determined approximately. The present maps have these divides shown incorrectly.

23. A reconnaissance trip was made to study the trimlines of the Berners Bay "trench" near Camp 15 in the northwest part of the ice field.

24. The trimlines and the recessional behavior of Lemon Creek and Ptarmigan Glaciers were studied.

25. Trimline and geobotanical studies were made on the lower Norris Glacier, between Norris and Taku Glaciers, and near Taku Point. These investigations were made to collect more information on and to date the previous advances of Norris and Taku Glaciers.

26. The present ice level of Norris Glacier was marked by various paint marks on the rock walls.

27. The terminal regions of Herbert and Eagle Glaciers were visited to collect evidence on the extent of post-Pleistocene changes in the the elevation of the land.

28. Much of the data collected this and previous years is being used to check the mathematical theory of glacier mechanics.

29. Various observations were made on stream cutting processes on glacier ice. Glacier ice is ideal for such studies in many respects as ice is more uniform in nature than most rocks and soils.

30. Various observations of a glacial geological nature were made on the flow behavior of ice, importance of glacier-dammed lakes in determining glacier flow, and on the streams of water inside and beneath a glacier.

VIII. RECOMMENDATIONS FOR FUTURE WORK ON THE JUNEAU ICE FIELD

1. Study the movement and changes of crevasses and ice falls by time-elapse photo studies. This requires a camera with a special device to take a single frame at a time on 16 mm or 35 mm movie film every few minutes. Such an investigation carried out for a full season should give an interesting movie that might give clues to the solution of several problems on crevasses, ice falls, and the formation of ogives.

2. There is a great need for accurate ablation data on the ice of the Taku Glacier from the terminus to the firn line and extending from the beginning to the end of the season. The important thing is to get the total amount of ice melted after the winter snow has disappeared.

3. Snow and movement studies are still needed on Norris Glacier to compare with the Taku.

4. If a simple way can be found to measure it, the amount of slippage of ice over the bed of the glacier should prove extremely interesting. It is not known what part of the movement of a glacier is due to flow and what part is due to sliding. This is an important variable in the theory of glacier mechanics.

5. It is not known how the erosive power of a glacier depends upon the thickness of the ice. Like the problem listed above, this seems to be a problem that is not easily studied.

6. Short time (hourly or daily) measurements on the movement of ice are important from the theoretical standpoint. Do glaciers move smoothly or by jerks? Extreme care and accurate techniques are required to get meaningful results. Highly crevassed areas should be avoided as they undoubtedly do not move smoothly.

7. There are various problems in connection with medial moraines. Is there enough rock material in a moraine to slow up its movement with respect to the clean ice on either side? How are the unusual twisted moraine patterns found on some glaciers formed? How do moraines that suddenly change in size originate? What does the change in spacing between moraines as they go down glacier tell about the underlying topography, the amount of ice being contributed by the various branches, etc.?

8. There are numerous problems in hydrology involving streams on the surface of glaciers, inside glaciers, and underneath glaciers.

9. What is the effect of melt water on glacier flow? Does movement of ice differ between summer and winter? Measurements should be made both above and below the firn line.

10. Careful studies should be made on waves of ice advancing down glaciers. Possibly these waves can explain the periodic behavior found in the retreat of some glaciers as evidenced by numerous recessional moraines. What is the cause of these waves, and how do they fit into the general theory of glacier movement? Many accurate longitudinal and transverse topographic profiles are useful in such a study. Measurements should be made on several successive years to tell how the waves move and whether the waves are truly waves or just manifestations of underlying topography. (This year's proposed program along this line had to be greatly curtailed.)

11. The glacier in Berners Bay "trench" would be an interesting area for special studies on: ogives, ice-dammed lakes, squeezing together of medial moraines, and the strange moraine that shows an abrupt change in size (see aerial photo SEA 125-021).

12. It is important to have more senior scientists to help the younger men. At the same time the younger men will get better training. In most cases these senior scientists should be picked to work on a specific problem. Such an organization of the project would probably lead to several small and fairly independent parties being in the field at the same time. Several parties working on the ice field, of course, make the logistical problems more complicated. However, by having a man whose only job would be to take care of the logistics, these complications could be minimized.

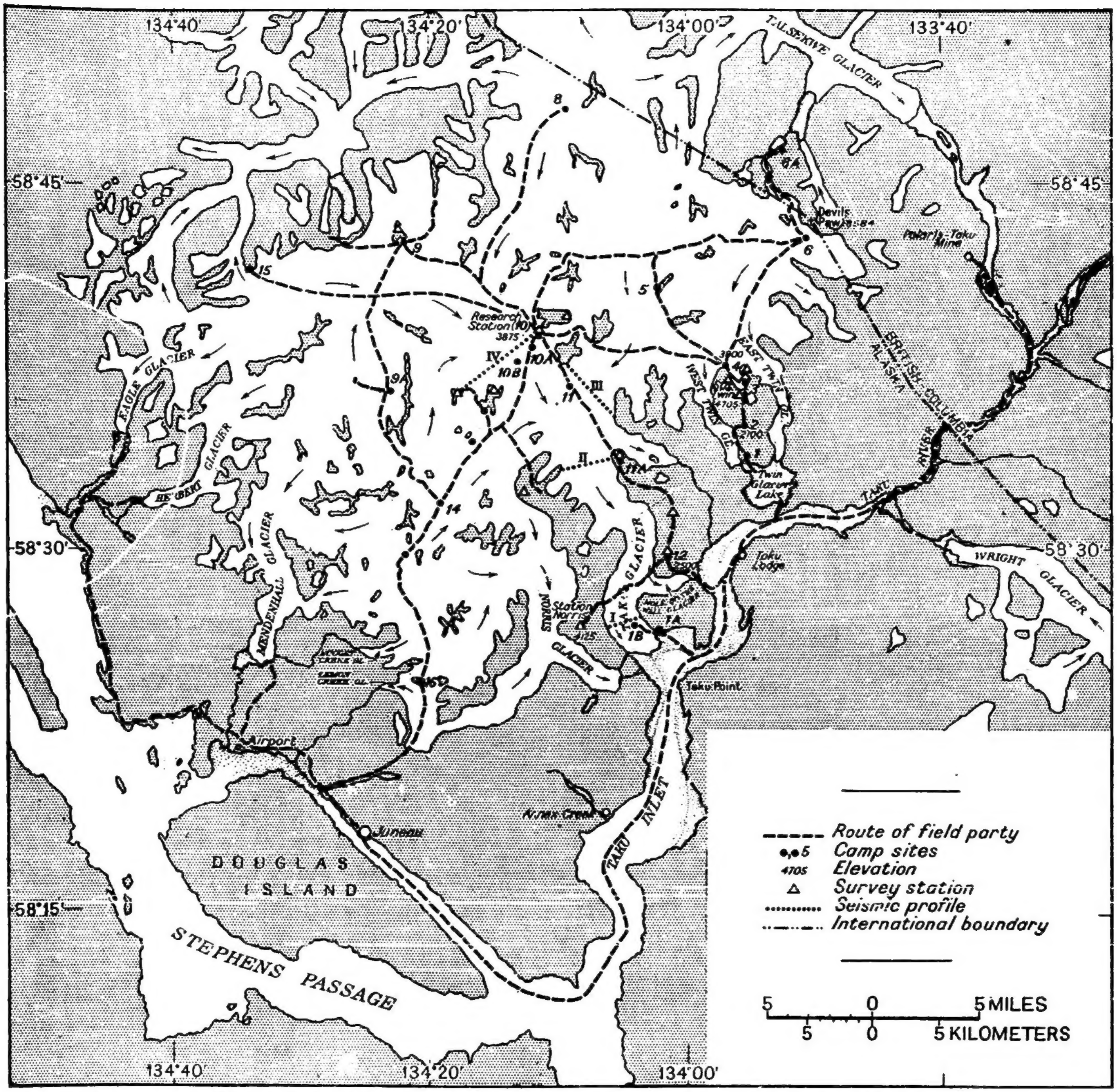


Fig. 1. Sketch map of the Juneau Ice Field and vicinity. Modified from map appearing in the *Geographical Review*, Vol. 40, 1950, p. 195.